PUERTO RICO INDUSTRIAL DEVELOPMENT COMPANY
COMMONWEALTH OF PUERTO RICO

FINAL REPORT

SITE SCREENING STUDY FOR DEEP WATER PORT AND INDUSTRIAL COMPLEX

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VAN HOUTEN ASSOCIATES, INC.
NEW YORK

PUERTO RICO INDUSTRIAL DEVELOPMENT COMPANY

COMMONWEALTH OF PUERTO RICO

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DEEP-WATER PORT AND INDUSTRIAL COMPLEX

1973

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(For Appendix See Volume 2)

Van Houten Associates, Inc.

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SYNOPSIS

There is a need for new oil refining capacity to strengthen Puerto Rico's existing petrochemical industry, as well as to further its industrial development.

For both the existing industry and new refineries, new deep-water port facilities, are required. While it is expected that Puerto Rico's refineries will continue to import much of their oil from Venezuela, any major expansion, as with the rest of the United States, must be supplied from the Middle East. The volumes and the distances from this source make transportation by VLCC tankers inevitable.

Trends in the United States' petroleum industry create an expanding market for petroleum products from offshore refineries. Because of its location, as well as recently inacted import regulations, Puerto Rico is in a particularly favorable position to share in that market.

If Puerto Rico's refinery industry moves quickly enough, before alternate sources have been developed and fixed, it can be expected to capture a substantial part of the East Coast U.S. market. By exploiting this opportunity, Puerto Rico's refining industry could be expanded to a much larger size than would ordinarily be the case. The development of a very large refining industry in Puerto Rico should help insure availability of petroleum products to local users and at more favorable terms than would otherwise be the case.

The object of this study is to determine the most favorable sites for possible development of a major new petroleum refining center and deep-water port.

Secondarily, the sites were considered for other types of port development. All of Puerto Rico was screened for possible sites. A number of potential sites were identified on the west and south coasts and on the offshore island of Mona. Considering cost, together with social, environmental, ecological and flexibility factors resulted in three most favored sites: Añasco, Aguadilla and Isla Mona. Otherwise attractive alternate sites at Punta Cabullon and Guayanilla on the south coast were discarded as petroleum ports for environmental reasons.

Isla Mona is best suited for a large scale development with emphasis on export products. The main island sites appear best suited for a more modest development aimed primarily toward the Puerto Rican internal demand.

Selection of the level of development is beyond the scope of the study, but it is obvious that large scale development would result in greatest economic return with substantial secondary social benefits due to increased Treasury revenues. On the other hand, a smaller development, by requiring less land and possibly resulting in less environmental damage, would initially result in less adverse social impact. This could be important for sites located on the main island.

Development on Isla Mona could result in the large scale petroleum port with related major refining, petrochemical, and other heavy industry, without causing pollution on the main island, or committing land presently used for other socially desirable purposes. Development on Isla Mona would also leave main island port sites free for alternate development of basically non-polluting activities.

Should Puerto Rico proceed with a deep-water port and new petroleum industrial center, development is recommended under a special governmental agency. In the interim, to expedite the program and shorten time schedules, it is recommended that execution be under the direction of PRIDCO and the Economic Development Administration. Timing is most important with the proposed development to ensure its success. To maximize potential, an operational target of late 1976 to 1977 should be established with all activities committed towards this goal.

Environmental, engineering and basic cost development programs should be initiated immediately. Concurrently, negotiations with potential users should be initiated and carried out with the objective of developing financing for both the preliminary and latter stages of development. It is recommended and believed feasible, that the complete financing of government facilities can be carried out without general Treasury backing and with recovery of investment from user fees and tariffs.

1.0 INTRODUCTION

1.1 General Background

Studies of industrial ports in Puerto Rico have been carried out at various times over a number of years. All investigators have agreed that new industrial port facilities would be desirable. There has been some difference of opinion regarding the best location and plan for development, but nearly all agreed that a petroleum activity would necessarily be an active and major part of the port development.

Recent trends in the world petroleum industry have affected Puerto Rico and have caused an escalation of the need to study and consider special deep-water port facilities for the petroleum industry in Puerto Rico. Recent studies to strengthen the industry have considered cases ranging from simply providing a new VLCC tanker berth for existing Puerto Rican refineries, through central transshipment terminals, to development of a new petroleum and petrochemical processing area near a new major port.

These studies have revealed considerable potential economic benefit to Puerto Rico by the development of a major petroleum petrochemical industrial complex with a deep-water port. Preliminary site screening studies have indicated that there are several locations for potential development of the port. Different investigators have given varying and sometimes conflicting opinions as to the most desirable location.

In addition to petroleum facilities, some investigators and authorities have concluded that other major industrial developments will benefit by a deep-water port in Puerto Rico. While the economic analyses of these other activities have not advanced to the degree of those for the petroleum industry, there is strong opinion among some authorities that such port and industrial use should be included in any study of a petroleum deep-water port.

In an attempt to clarify and resolve the differences of opinion regarding the most desirable location of the port and industrial complex, and its possible development, this site screening study was commissioned.

1.2 Facility Requirements

Requirements for facilities depend on the degree of development proposed. The basics include deep-water berths for VLCC petroleum tankers, and possibly for heavy bulk carrier vessels; shallow depth berths for petroleum product tankers; and possibly others for container ships, other special bulk and cargo vessels and local craft. Also required are petroleum piping and pumping systems, petroleum tank farms, processing facilities with appurtenances and off-site facilities, possibly other heavy industrial facilities, internal product distribution systems and the various support and utility systems to make the project viable. Relatively large blocks of land are required for development of the industrial facilities. It should be basically suitable for the development, relatively uninhabited and, ideally, not suitable for agriculture, residential, or other socially-desirable use. Finally, the full development must take into account environmental and ecological impact.

1.3 Study Objectives

The objectives of the site screening study are as follows:

a. Identify the potential deep-water port sites in Puerto Rico and the offshore islands.

b. Screen the potential sites for general suitability, probable relative cost, social and environmental impact, present and future flexibility for development and future potential. Select about five of the best potential sites and compare them in some detail for the foregoing factors.

c. Compare the economic attractiveness of the sites, both within themselves and as compared with competing sites, to serve potential off-island markets.

d. Recommend the three best alternative sites for the project.

e. Recommend future studies and action for the selection of the final site and the implementation of the project.

1.4 Authority

Authority for this study derives from a contract dated 24 May 1973 between the Puerto Rico Industrial Development Company and Van Houten Associates, Inc. Terms of Reference from the contract are given in Appendix A.

1.5 Methodology and Report Organization

A major technique for carrying out the study was to utilize available basic data and findings from other studies for re-analysis as they apply to the new deep-water port. Other work items included the following:

a. Establishment of petroleum requirements for Puerto Rico.

b. Establishment of future petroleum industrial opportunity for Puerto Rico.

c. Establishment of other possible port and cargo requirements.

d. Establishment of facility requirements for four cases of development, based on alternate means of meeting Puerto Rico's petroleum requirements.

e. Examination of charts, maps, meteorological data and oceanographic data to identify the physically practical and potential port and industrial sites.

f. Examination of available data to determine approximate relative cost, social and environmental factors and other factors that might influence selection of the port.

g. Field verification of certain critical but incomplete site data.

h. Preliminary screening by qualitative comparison of potential sites in order to select the five or six most promising.

i. Preparation of reasonable layouts for port and industrial development to suit the four cases of development proposed.

j. Examination of the economic factors related to the petroleum development.

k. Comparison of the relative factors of cost and economics, social impact, environmental impact, potential flexibility and prospects for future development of the various sites for each case.

The organization of the study report generally follows the procedure and method of the study. Where possible, tables of data are used to facilitate comparison. Illustrations and figures are included to assist with visualization of the development.

Suggested layouts and plans for development as shown in this report are not necessarily the ideal for a site but are reasonable for comparison purposes and are subject to further study, refinement and optimization. Layouts were prepared to permit development of approximate comparitive costs.

Economic data presented are for background and to assist with site comparison. This report is not intended to be used to substantiate the economic desirability of the project. The general data given are sufficient to indicate the general feasibility of the plan at a site, but not the optimum development.

The social and environmental impact data and analyses are intended primarily for site comparison purposes. While the report is useful in preparing for an environmental study, it is not intended to be a substitute for the environmental impact analysis and statement required by present laws and regulations in Puerto Rico and the United States.

Major sources of data and names of persons and organizations from whom helpful information was obtained are listed in Appendix B.

2.0 SUMMARY

2.1 Petroleum Requirements for Puerto Rico

The petroleum and petrochemical industries have made a substantial contribution to furthering Puerto Rico's economy and industrialization. The first refinery started operating in 1955 and was followed in the 1960's by an additional refinery and several petrochemical plants. A third refinery was brought on stream in 1972, and additional petrochemical plants have been under discussion. At an average annual growth rate of 12%, the petroleum and petrochemical industries are among the fastest growing industries in Puerto Rico. The social desirability of these industries for development in Puerto Rico is indicated by their history of substantially higher than average earnings, their low accident and injury rates, and the stability of employment for the engaged work force.

The economic attractiveness and viability of Puerto Rico's petroleum industry in the past have depended on its proximity to sources of relatively plentiful and cheap crude oil and unfinished petroleum products in Venezuela and the Netherlands Antilles, combined with the ability to sell products' excess to Puerto Rican requirements to the continental U.S. mainland. With this combination, Puerto Rico was able to develop and support a larger and more complex industry than would otherwise have been possible, and Puerto Rican consumers--including its electric power authority--were thereby furnished lower-cost petroleum products than would otherwise have been possible.

For a while, U.S. Federal controls restricted the Puerto Rican petroleum industry from fully exploiting its advantageous position. These restrictions have recently been removed, and Puerto Rico is now in a very favorable position to take advantage of a substantial petroleum market opportunity. But, in the meantime, certain developments have occurred in the world petroleum industry that could not only impede such a goal for the Puerto Rican industry, but also endanger its present position.

Of these developments, the unforeseen great increase in world demand for unfinished naphtha (the main petrochemical feedstock) has had, and promises to continue to have, the greatest detrimental effect. This increase of demand has turned the supply of naphtha from surplus to scarcity, has caused its price to more than double, and has made traditional sources of supply uncertain. The world demand for unfinished naphtha appears to be on a permanently rising trend as both Europe and the United States rapidly increase their consumption, both for petrochemical feedstock and for use in making so-called clean energy fuels.

To protect the existing petrochemical industry and to further its development as a cornerstone of Puerto Rico's industrialization, secure and economical sources of naphtha are required. The most secure and probably most economical source of naphtha would be to make it available from a Puerto Rican refinery.

This appears to require new refining capacity in Puerto Rico. The existing three refineries have a combined capacity of about 250,000 barrels per day and turn out a comparatively small amount of naphtha. While there is undoubtedly some flexibility of operation and yield possible with the existing refineries, it does not appear feasible for them to supply more than a fraction of the current naphtha requirements.

Naphtha imports into Puerto Rico are currently running at a rate of about 150,000 barrels per day. New refinery capacity of about 500,000 barrels per day is required to develop an economically viable domestic source of naphtha to take the place of these imports.

In addition to naphtha, Puerto Rico requires additional supplies of fuel oil for its power plants. Current rate of consumption of fuel oil and residuals is between 70,000 and 72,000 barrels per day. Existing refineries produce about 70,000 barrels per day. Supply and demand are presently close to balance, but projections by PRWRA indicate fuel oil requirements will double by 1980, with additional increases beyond that uncertain and dependent on whether or not nuclear power plants are in operation. It is probably that successful continuation of the industrialization program will both accelerate the demand and continue its growth beyond 1980, even if nuclear plants become a reality.

Besides the projected increase in consumption of fuel oil, there is expected to be an increase in refinery demand due to higher quality standards. Low sulfur fuel regulations by the EQB require either rebuilding of existing refineries or replacement, in order to yield fuel oil of the required specification. Economic realities indicate replacement as more likely.

Conservative projections of Puerto Rico's growth of demand for all petroleum products indicate an approximate threefold increase in requirements by

1985. This represents a future consumption of some 800,000 to 900,000 barrels per day of products, including petrochemical feedstock and heavy fuel oils for power plants. The assumptions of growth for both these products are based on continuing development of industrialization within Puerto Rico and a reasonable growth of the economy. Failure to encourage this growth could result in considerably less demand, but the social consequences might be unacceptable.

Four cases have been assumed for meeting Puerto Rico's petroleum product demand. Sites and tentative development plans and associated distribution systems have been compared for each case. Case A assumed no increase in current refining capacity with increased product demand met by imports from off-island refineries. In Case A, in addition to studying new, large central import terminals, consideration was given to installing new import terminal facilities at each of the three major population centers and at the two major petrochemical centers.

The other three cases all considered meeting Puerto Rico's increased product demand through new refinery expansion within Puerto Rico itself. Case B assumed existing refineries would expand in proportion to their present share of total refining capacity. Case C assumed establishment of a new refining center to primarily serve internal product demand but with export of excess products. Case D assumed a larger refinery in order to take advantage of substantial product export opportunities as well as to meet internal demand.

2.2 Petroleum Opportunity for Puerto Rico

Puerto Rico's opportunity stems from the same basic factors that presently cause distress to its petroleum and petrochemical industries. The loss of Western Hemisphere self-sufficiency in petroleum, coupled with increasing world demand, has made traditional oil supplies uncertain and costly. The need for the United States to import increasingly greater volumes of oil, to eventually become the world's largest importer, can only reinforce this trend.

The solution in part is to develop alternate sources of supply. This means primarily the Middle East. The Middle East, with about three-quarters of the world's known oil reserves, is presently the chief source of imports for Europe and Japan and appears destined to become the same for the United States (see Figures 2 and 3).

To develop these far distant alternate sources of oil using traditionally sized tank ships for transport would be both costly and hazardous.

Facilities to permit the use of VLCC (very large crude oil carriers) tankers are required in Puerto Rico as well as in the continental United States. The lack of such facilities would place a costly and depressing burden on the general economy of Puerto Rico as a whole as well as specifically on its petroleum industry. On the other hand, provision of such facilities would put Puerto Rico's energy base on an equal footing with that of other oil importing economies.

The ability to import crude oil from the Middle East in VLCC tankers would allow Puerto Rico's petroleum refineries to compete on a cost basis with many other refineries in the United States, especially those on the East Coast. Recent revisions of U.S. oil import regulations placed Puerto Rican refineries on an equal legal basis with continental refineries. Considering its favorable location on shipping routes (see Figure 1), its proximity to Northeast U.S. markets, and its special advantages regarding tax and import duties, a larger future Puerto Rican refining industry should now find itself highly competitive in the Northeast U.S. market.

The Northeast region comprises the United States' largest market and for petroleum, the most dependent on imported oil. The projected demand for petroleum products in this region in the next 10 to 20 years represents a very large and increasing market. Traditional sources for Northeast petroleum products, including local refineries, U.S. Gulf Coast refineries, Canadian refineries and other foreign refineries, particularly in the Caribbean, can be expected to continue to share in the market for the future, but all appear to have competitive disadvantages when compared with Puerto Rican refineries.

This means that, on a straight economic basis, it should be possible for Puerto Rican refineries to develop a market in the Northeast United States almost at will. Other factors can be expected to limit the actual market developed. The potential would probably still be many times the supply ability of refineries located in Puerto Rico. In the near future, products refined in Puerto Rico that are in excess to Puerto Rico's needs should be freely disposed of at attractive prices. Other products from new refineries will depend on timing as well as price for market penetration.

Petroleum supply agreements are usually made on a long-term basis and supply sources cannot easily be displaced once a commitment has been made, no matter how attractive the price otherwise. Puerto Rico, with proper planning, has the opportunity to share the U.S. Northeast market and satisfy its own requirements. With intelligent planning as to product mix and pricing, this should result in the lowest possible cost of products to the consumer with Puerto Rico itself. The advantages to the rest of Puerto Rico's economy are obvious.

2.3 Petroleum Facility Requirements

2.3.1 Refineries

The refining capacity required to meet Puerto Rico's petroleum product demands will depend on process design, the crude oil feedstocks, environmental requirements, economic conditions and desired export levels. Refinery optimization is beyond the scope of this study, but assumptions as to size and general produce yield are required for meaningful site screening.

It has been assumed that the new refineries would yield about 50% of the crude oil run in the form of fuels and naphthas and the remainder in consumer products. For Cases B and C, it has been assumed that all of the fuel oils, residuals and naphthas would be used within Puerto Rico along with a portion of the consumer products. The surplus products would be exported. Case D assumes all of the product yield from a large additional refinery capacity would be exported in addition to that from Case C.

Assumed New Refinery Requirements

	Cases B and C To Serve Primarily Puerto Rico	
	Capacity (BPD)	Surplus for Export (BPD)
1975	500,000	250,000
1980	800,000	380,000
1985	1,150,000	500,000
1990	1,600,000	700,000

	Case D To Serve Puerto Rico, Plus Export	
	Capacity (BPD)	Export (BPD)
1975	1,000,000	750,000
1980	1,800,000	1,380,000
1985	3,000,000	2,350,000
1990	3,600,000	2,700,000

2.3.2 Terminal

The terminal facilities required for Cases C and D include VLCC tanker crude oil import berths, product tanker export berths, berths for local tankers and barges, and a service harbor as well as oil discharge and loading systems, a terminal tank farm, various tugs and service craft, pollution control and safety provisions and support facilities. In addition, it would be desirable to have an anchorage for waiting ships.

For the new Case B terminal, the same facilities are required, except for the product tanker export berths. It is assumed these would be provided at the existing refineries.

For Case A, new product tanker import berths are required instead of export berths and crude oil import berths. With this exception, a new central product import terminal would be similar to a terminal for the other cases. The multiple terminals at consuming and use centers would be smaller in scale, but with similar components. Considerable duplication of facilities is assumed in this case.

Assumed New Berth Requirements

	Case A		Case B	Case C		Case D	
Year	Central	Mult.	Import	Import	Export	Import	Export
1976	2	5	2	2	2	4	8
1980	3	5	2	2	3	6	10
1985	4	6	3	3	4	8	14
1990	5	8	4	4	4	8	14

The crude import berths are assumed designed for VLCC tankers of 250,000 to 500,000 DWT in regular use. They would also be designed for accommodating occasional larger tankers of 600,000 to 700,000 DWT as well as some of the larger export tankers. The product export berths are assumed to accommodate 60,000 to 100,000 DWT export tankers on a regular basis, with occasional use by tankers of 150,000 DWT and barges of about 30,000 to 40,000 DWT.

Both pier, or platform, type berths and SPM (single-point mooring) type berths have been considered. Each has its advantages and disadvantages, with suitability and preference depending on site conditions and general requirements.

Where site configuration allows sufficient area of suitable water depth, neither too shallow nor too deep, for ships to approach and depart from required directions and to safely swing 360 degrees while in berth, SPM berths are suitable. Where sea conditions are rough, they may be the only solution. Where the number of berths required is few, they may be the most economical.

On the other hand, where berthing area is limited and the number of berths required is large and sea conditions are mild, platform or pier berths are usually more suitable.

There are few places in Puerto Rico where water depths are suitable for SPM berths in the numbers required.

The site screening study has therefore been based on pier or platform berths. After a site has been selected, the optimum berth design can be developed.

Pile-supported, platform and dolphin type structures with high-capacity energy-absorbing fenders were assumed for the berths. Metallic loading or unloading arms with welded steel piping were assumed for efficiency and safety of the loading and discharge systems. Discharge rates up to 25,000 tons per hour and loading rates of 10,000 to 15,000 tons per hour would be accommodated. These rates would result in total port turnaround times of about 36 hours for VLCC's and 24 hours for product tankers, allowing for berthing, deberthing, ballasting and deballasting and other port time.

The terminal would include a tank farm to smooth out the variable oil flow from tankers either discharging or taking on cargo. Included in the tankage would be oily ballast water tanks and equipment for treating any excess ballast water not needed by vessels after unloading.

It is assumed that all the petroleum port facilities will be designed, constructed and operated in accordance with modern standards using the best technology to achieve safety and to minimize oil spills and essentially eliminate atmospheric pollution. All equipment for coping with emergencies such as fire and oil spills would be provided.

Tugs and other small craft to service the tankers are required and would be provided along with a safe all-weather service harbor for storm shelter.

2.3.3 Ancillary Support Services

The petroleum terminal would in itself be a relatively moderate consumer of fresh water, electric power, fuel and waste disposal facilities. The requirements would be small compared to those for the large refinery and other industrial installations contemplated for Cases C and D, and have been incorporated with them. At all sites studied, some additional to existing capabilities would be required, even for Cases A and B, but have only been cost estimated for Cases C and D.

Initial requirements for a major industrial facility are assumed to be:

Fresh Water - 8.0 million gallons per day, minimum, with 10.0 to 15.0 million gallons per day recommended.

Sea Water - 40 to 50 million gallons per day for cooling.

Electric Power - 200,000 KW

Fuel Supplied by refineries or barged in.
Waste Disposal - Industrial waste, process dirty cooling water.
Ballast water from ships.
Domestic wastes for new nearby housing.

2.3.4 Oil Distribution Systems

To conduct the projected additional volumes of products to Puerto Rican users from the new refineries, it is assumed that new distribution systems are required. Existing systems shown on Figure 9 include an industry owned and run products pipeline from Guayanilla to San Juan as well as a barge system and tank trucks over the road. It has been assumed in the study that these would continue in service, handling volumes at about their present level, except for Case B. Some expansion has been assumed for Case B, but not included in the study cost comparisons.

For site comparison cost estimates in Cases A, C, and D, a government financed primary pipeline distribution system was assumed to move consumer products from the new refinery or terminal site to three assumed centers for secondary distribution by private companies to the consumer. Also, government financed pipeline distribution of feedstock to the two main petrochemical centers was assumed.

In Case B, a crude oil pipeline distribution system was assumed to move crude from the import terminal to the three existing refineries, except for the Mona site, which requires barges.

Privately operated barges were assumed for distribution of heavy fuel oils and other products not compatible with the pipeline products. Barges would also be required for distribution of all products from the Mona Island site.

2.4 Possible Other Port Requirements

Consideration of possible other port and industrial facilities in addition to those for petroleum has been included in Cases C and D of the site screening study. The possible requirements for these other facilities are based for the most part on a study of port-related industries prepared by Arthur D. Little in 1960. Based on a brief appraisal of the present-day likelihood of developing such facilities and of their suitability as adjuncts to the petroleum deep-water port, tentative development plans have been included to show potential locations for the marine installations and the land that might be used.

The appraisal confirmed the possibility that a small to moderate size steel mill and possibly other metallurgical plants, would be feasible. This would require port facilities consisting of dry bulk cargo vessel berths served by conveyors to handle the ore and coke between the berths and onshore storage piles areas.

In some cases, it might be possible to combine petroleum products and bulk cargo berths, but for site screening, the bulk and other cargo berths have been developed separately from the tanker berths to avoid confusion. Berths with 60 to 70 feet water depth have been assumed for metallurgical bulk cargo ships.

Facilities for super container ships could also be incorporated in the port development. These are not usually considered an integral part of a deep-water industrial port, but have been considered for general space requirements where feasible.

Water depths of about 40 feet would accommodate these type ships for the foreseeable future. Some of the newer container ships have lengths of about 1,000 feet and berths of these dimensions will be required. In addition, for container operations, a wharf with special handling cranes, a clear apron of at least 100 feet and adjacent back up area of about 500 feet additional would be required. Breakwater protection is required to insure still water during lifting and setting operations. Other special ships, such as trailer ships, Roll-On-Roll-Off and LASH could be accommodated at the container ship berths if required. The need for these type vessels in Puerto Rico is uncertain if not questionable.

A general port is not usually an integral part of the deep-water port development, but such a development is possible at some locations by providing an expanded and deeper service harbor.

The general port facilities considered include marginal wharves with unobstructed, clear and paved aprons and provision for transit shed.

Passenger ships could also be accommodated in the general port, but since none of the sites studied seems likely to attract a large amount of this traffic, special facilities were not assumed. Passenger ships could be accommodated at the normal freight wharves on an occasional basis.

It is also possible to incorporate general port facilities in the special container ship or bulk cargo harbor, if one is provided. Greater water depth than necessary for a general port would be then provided, increasing the cost of wharf facilities. Care must be taken in the case of bulk cargo operations to avoid other cargo contamination from bulk materials blowing across berths.

While ship building and repair is a port-related industry, it is not normally considered an integral or necessary part of a deep-water industrial port. Especially not a port for petroleum. The main advantage for locating ship repair facilities in a petroleum port is that the existence of petroleum processing facilities gives the potential for cheaper, more efficient and safer tank cleaning of ships preparing for dry docking and hot repair work. Because of its size, Puerto Rico could achieve this advantage with facilities located anywhere around the island.

Also, a shipyard does not require very deep water. Even for VLCC service, water depths of 40 feet or even less would be adequate since the ships are light. For these reasons, we have not included a shipyard as a part of the site screening.

2.5 Site Screening

The site screening has been based primarily on suitability for the petroleum facilities. All of Puerto Rico, including the offshore islands but with the exception of the southwest corner between Punta Vaquero and Mayaguez, were examined for potential sites.

A number of potential sites were identified. By preliminary screening, they were narrowed down to seven for further study. The seven were then compared for general suitability, cost, social and environmental impact and flexibility for initial and future use.

2.6 Site Comparison

2.6.1 Cost Determination

Estimated capital costs and operating costs for the economic comparisons are for the facilities that would be owned and operated by the government. Briefly, these include navigation aids, any necessary dredging, berthing structures, their connecting oil pipelines and utility conductors, service craft, terminal tanks, and the land areas shown on the tentative plans for development, together with support facilities, such as a power plant, water supply system, common waste treatment facilities and other things such as common use roads. Also included are the product and crude oil distribution pipelines. Not included are the capital costs for mobile oil transport equipment such as trucks and barges which were assumed to be privately owned and operated. Estimated barge hire costs were included.

Costs are based on coordinated development to handle the projected 1985 volumes, and the estimated total throughputs for the 10-year period 1976 through 1985. All costs are estimated on the basis of 1973 dollars and 1973 construction cost levels.

Funds borrowed to cover the capital costs were assumed to be repaid in equal quarterly installments, each consisting partly of interest and partly of principal repayment, over a 10-year period at an annual interest rate of 6%. The total interest as well as maintenance costs are included under the general heading of "Operating Cost."

2.6.2 Cost Comparisons

In Chapter 9.0, the sites are compared for each development case on the basis of both capital and operating cost. Full recovery of capital and operating cost in a ten year period was used as both an indication of required revenue and a cost rating index for comparing sites.

These comparisons indicate that for Case A, multiple terminals for delivery of imported products direct to the using centers is the least costly alternate by a considerable margin. Of the central terminal schemes, Punta Cabullon is the cheapest, followed closely by Guayanilla and then either Añasco or Aguadilla, which are about the same.

For Case B, a central crude oil import terminal at either Punta Cabullon or Guayanilla would be cheapest, followed by Añasco and Jobos and then Aguadilla. A terminal at Isla Mona is among the cheapest from a capital cost standpoint, but the operating costs of barge transportation of crude oil over-balance its capital rank and make it overall excessively expensive for this purpose.

For Case C, a refining center and terminal at either Añasco or Punta Cabullon would be cheapest, followed by Guayanilla and Aguadilla and then Jobos. A similar installation on Isla Mona is more expensive than the others because of the distribution costs of internally consumed products, but its capital requirements are among the lowest.

The ranking for Case D is similar to Case C, except that Aguadilla is no longer suitable and the overall cost difference between Isla Mona and the other sites is narrower. This indicates the suitability of the Isla Mona site for a very large installation, especially including trans-shipping and export.

Considering all cases, Punta Cabullon and Añasco are the preferred sites from a cost viewpoint. Isla Mona is the more expensive site for internally consumed products, but is competitive for export products, especially with a large installation.

2.6.3 Demographic and Social Impact

Considering the effect on the populace, improvement of employment, removal of homes and other social factors, the leading selected main islands sites appear similar. Punta Cabullon and Jobos may be slightly ahead in beneficial versus adverse effects, followed by Guayanilla and Añasco, and then Aguadilla, but all are considered so close that this impact cannot be considered decisive.

At the south coast sites, the unemployment rate is reported to be somewhat higher than Puerto Rico's overall average and on the west coast it is much higher. Development of any of the leading sites would lead to an improvement of employment conditions.

Fewest homes would require relocation at Punta Cabullon and Jobos followed by Añasco and then Guayanilla, with Aguadilla having the most. Isla Mona, being uninhabited, is in a class by itself and could be considered an opportunity for urbanization to relieve development pressures elsewhere. Development on Mona appears to give the potential for greatest possible benefit with least adverse impact on the main island populace.

2.6.4 Environmental and Ecological Factor Comparison

The most serious environmental danger comes from a possible oil spill. At the south coast sites, the westerly ocean currents and prevailing south east winds would tend to carry spilled oil along the coast in that direction and some of this could be deposited along the shore. The prevailing currents at Añasco/Rincon and at Aguadilla would probably reduce the possibility of spilled oil coming ashore. Spilled oil at the Isla Mona terminal would probably be carried northward into a large expanse of open sea where it would be dispersed widely. Because of the apparent danger of spilled oil reaching shore at valuable estuarine, mangrove and recreational areas on the south coast, some government agencies have suggested avoiding further oil terminal development at any site on the south coast. This would leave only Añasco, Aguadilla and Isla Mona for further practical consideration.

For Cases A and B, there would be essentially no air pollution at any of the sites, unless a new power plant were located nearby because of the availability of residual fuel in Case A or of burnable crude oil in Case B. For Cases C and D, possible air pollution is a consideration even if power plants and refineries use low sulphur fuels. If metallurgical industries were to be included in the development, there could be considerable air pollution potential.

With the city of Ponce a short distance downwind of Punta Cabullon, this site is practically eliminated for industrial development for this reason. Also, because of the present air pollution, Guayanilla is not favored.

At Añasco, the winds are normally easterly, but calm, and onshore winds are prevalent at certain seasons. Further study is required to determine the seriousness of the air pollution threat at this site. Isla Mona is exposed to the trade winds with a large sea area downwind and potential air pollution would be normally so diluted as to be no threat. While Aguadilla has more of an air pollution potential than Mona, it is considerably less than at any other main island site.

In summary, Isla Mona presents the best site, by far, from an environmental standpoint, especially as it affects humans. Opposed to this, it is the most attractive site to ecologists because of its relatively undeveloped condition. Many ecologists and some government agencies have expressed a preference for Aguadilla and, secondarily, Añasco over Isla Mona. This preference has been so strong during the course of the study that, at times, it was considered that Isla Mona would not be available and should be dropped from consideration.

2.6.5 Flexibility

With the exception of limitations due to potential air pollution drifting over the city of Ponce, Punta Cabullon is the most flexible site examined. The extent of available land, the even shoreline and the expanse of protected water with suitable bottom conditions make it the best for flexibility of arrangement of the initial installations as well as for later ones. In particular, it could be undertaken for Case B or C levels and increased later to the Case D development with little difficulty.

While Añasco has considerable flexibility, conditions are not ideal for containership or general dry cargo vessel berths. These would be better located at the nearby port of Mayaguez. If Case D levels of petroleum activity were desired, there is insufficient nearby land north of the river for a metallurgical industry. However, some of the refinery installations could be located at Rincon or near Aguadilla and connected to the Añasco port by pipeline, thus allowing the metallurgical industry to be sited near Añasco.

Guayanilla has limitations on flexibility. Considerable area must be reserved for the diversion of flood waters. There is no good location for containership and dry cargo berths and the associated land areas needed. For the Case D development, extensive dredging would be required, not only to provide sufficient berth development, but also to obtain fill for the additional land required.

The Isla Mona site's flexibility is limited only by the need to locate and orient the VLCC berthing structures along the 120-foot contour, and the need to reserve and protect a satisfactory wildlife conservation area.

Aguadilla has considerable limitations on flexibility of use, both present and future. It is unsuitable for a large facility development. It could, however, be developed for a steel mill or other port facility, Aguadilla could also be used for a refinery site to be served from an Añasco port.

2.6.6 Estimated Timing

The time between decision on any major project and its start of operation could vary greatly with the site, depending on the length of time to obtain permits, and to acquire land.

Aside from vocal opposition, which seems to have developed against all sites, it is estimated that land acquisition will take from 1-1/2 to four years at the main island sites. Isla Mona, being government owned, could probably be made available almost instantly.

If land acquisition was delayed until completion of environmental impact statements and permit granting, construction could be intolerably delayed until near 1980 at some sites.

If there is an overlap of land acquisition with the impact statements, engineering, financing and other tasks, the overall time could be considerably shortened. It would still vary from site to site and make some sites more attractive than others, to both meet Puerto Rico's need and to take advantage of the export opportunity.

In this regard, Isla Mona is much superior to any of the others. Of the main island sites, Punta Cabullon is best, followed by Añasco, Guayanilla and Jobos and with Aguadilla last to the point of not being feasible for first stage development.

2.7 Recommended Implementation

2.7.1 Further Studies

The following further studies are required for successful implementation of the project:

a. Social impact and planning to compare the sites and to determine the best overall course of action for Puerto Rico from the standpoint of population effects, employment, life quality, economic well being, and upgrading of social services.

b. Environmental impact including required field work, to compare the sites and to determine and evaluate probable and possible damage and to develop means to safeguard against damage by prevention and minimization of effects. To determine means of improving the environment while developing the project.

c. Economic impact and planning to evaluate the potential cost and benefits to the economy as a whole within the guidelines of the social and environmental impact studies. To develop an economic plan for the future to achieve the optimum between the two sometimes conflicting goals of social advancement versus environmental protection. To evaluate the cost to the economy of providing either social or environmental improvements through investment in the project. To determine other non-petroleum facilities to be included with the project.

d. Field investigations of sites for hard engineering data to supplement existing data, including soils and foundations, meteorology, oceanography, hydrology, bathymetry and topography. Some of these investigations can be incorporated with environmental studies.

e. Engineering planning and design optimization studies to further develop the best utilization of the site and minimum overall cost of facilities within economic, social and environmental guidelines.

f. Detailed financial feasibility of the project, including capital and operating costs, determination of optimum tariff schedule, estimated revenues, methods of finance, financial costs and procedures. This can be incorporated within the engineering planning and design study as close coordination is required between the two. Tariffs must cover costs and costs must not produce uneconomic or non-competitive tariffs.

2.7.2 Other Tasks Required

To bring the project to reality, other tasks include:

a. Organize project management team
b. Arrange financing
c. Execute detailed engineering
d. Let and manage construction contracts
e. Arrange contracts and agreements with users
f. Supervise users' development plans and execution
g. Organize or arrange operations and support activities

2.7.3 Recommended Procedure

There is considerable benefit to both Puerto Rico and the users in developing the deep-water port and industrial complex by a specially created government organization. This would give maximum assurance that the planning and execution would be most responsive to Puerto Rico's needs. Further, there are substantial cost benefits in government handling of the financing with lower interest tax-free bonds.

Disadvantages include the possibly greater time span in initiating the venture, the possible lack of sufficient experienced personnel for such a venture, and the possible risk to the Commonwealth of committing so much financial resource to a single undertaking.

On balance, the advantages of government execution appear to far outweigh the disadvantages.

Therefore, we recommend that the industrial center and deep-water port complex be developed under the direction of a special governmental group formed for the purpose. Existing government agencies and companies having responsibilities for some of the parts and phases of review should contribute to the special group, either through sub-assignments or by representation on the Board of Directors.

Further, since the timing of the development is most important, we recommend the preliminary work be undertaken immediately and before the new group is formed, possibly under the auspices of the EDA with execution by PRIDCO.

Some of this work, especially the environmental impact study, requires investigation of at least three alternate sites to conform with government regulations. This includes field investigations. For this reason, work could and should start immediately, even before the final site decision is made.

We recommend that Aguadilla, Añasco and Punta Cabullon be studied intensively, with further investigation of Isla Mona. We also recommend effective discussions with potential oil company users with the objective of obtaining their views as to site preference and level of development. Further, an attempt to obtain commitments should be made.

With even conditional commitments, it should prove feasible to advance the development work and planning to the point where interim financing of the preliminary work could be obtained.

The preliminary work, before detailed engineering and construction, may involve an expenditure of several million dollars. Funding of this amount from current revenues may present a difficult burden on the Commonwealth treasury. The feasibility of financing this work by contributions from prospective users and participants could be explored. Such contributions could be either in the form of participant fees or as advances to be redeemed and absorbed by the special revenue bonds that are to finance the project as a whole. It is our opinion that the project is in itself attractive enough so that it could be financed by revenue bonds to be paid for by tariff revenue and user fees without requiring treasury backing and without paying excessive interest rates.

Specifically, we recommend the government finance, build and operate, either directly or by contractor, the following facilities:

a. Terminal berths and tank farm and transfer systems to users' tank farm

b. Service harbor

c. Other possible port facilities

d. Ancillary support facilities and services
    - Power plant
    - Water supply
    - Waste treatment and disposal
    - Communications
    - Social services

e. Distribution pipelines

f. Distribution barge terminals

3.0 DESCRIPTION OF PROPOSED ACTIVITY

3.1 Petroleum Requirements

3.1.1 Current Conditions in Puerto Rico

The petroleum refining, petrochemical and allied industries constitute the fourth largest group within Puerto Rico's manufacturing sector, surpassed only by the apparel, food and electrical groups.

The petroleum industries in Puerto Rico represent about $1.3 billion in plant investment with direct employment of 7,800 and possibly twice that number of indirect support jobs.

The contribution of the petroleum group to Puerto Rico's economy and social welfare has been significant. Employment in the group has been increasing at a compounded average rate of 12% per year for the past 12 years. Average hourly earnings range from 150% to over 200% of the average for all manufacturing. With only slightly over 5% of total employment in manufacturing, dollar earnings of employees in the petroleum group equaled nearly 10% of the total for 1972. Further, unemployment, accidents and injuries have all had a favorable history compared to other industries.

The first refinery in Puerto Rico started operating in 1955, followed by a number of petrochemical plants, mostly built during the 1960's. Of necessity, since there is no local crude oil production, the industry is based on imported oil and has been subjected to special provisions and restrictions both for its own imports and in supplying U.S. markets.

Most of Puerto Rico's petroleum feedstocks have been traditionally imported from Venezuela or other Caribbean areas. Part of the reason for this is geographical. The original refineries and petrochemical plants in Puerto Rico were established to take advantage of Puerto Rico's proximity to crude oil production in Venezuela and the relatively cheap naphthas available from the refining centers of the Netherlands Antilles. Nearly free imports were allowed by the Federal government into Puerto Rico to supply its own needs, with limited shipments of excess products permitted to be shipped to the mainland.

In recent years there have been problems in this arrangement that have adversely affected the Puerto Rican industry and probably impeded its development. The most serious were the reversal of the world crude oil supply and demand situation with a fall off of Western Hemisphere crude oil availability and a sharp increase in price of Venezuelan crude. This has been accompanied by an unprecedented increase in world demand for naphtha which resulted in outright scarcity and prices that have more than doubled in recent months.

For a time, the Puerto Rican petroleum industry found it difficult to cope with its suddenly disadvantaged position because of the restriction in the then U.S. import regulations as well as because of economic reasons. The Federal regulations have now been changed to remove those restrictions and, to some extent, to give Puerto Rico certain advantages when compared to other areas of the United States. Only the economic problems now remain.

The heart of the petroleum/petrochemical industry is formed by the three refineries with a combined processing capacity of about 250,000 parrels per day.

Main Refineries

Owner	Location	Approximate Capacity (BPD)
Gulf Oil Corporation	Bayamon	40,000
CORCO	Peñuelas	125,000
Sun Oil Company	Yabucoa	85,000
Total		250,000

In addition, some of the petrochemical plants also produce some finished petroleum products.

The exact capacity of a refinery is difficult to define, as it varies with the feedstock run, the method of operation and other factors. Similarly, the products turned out sometimes vary. For this reason, as well as differences between agencies in reporting statistics, there seems to be difficulty in obtaining consistently conforming statistical data on the Puerto Rican industry as it exists today.

For the purpose of the site screening study, exact figures are not required. It is sufficient that they be reasonable and approximately correct, especially in regard to the determinant factors. With this in mind, we present our understanding of the approximate present conditions in the Puerto Rican petroleum and basic petrochemical industry.

Approximate Existing Conditions in Puerto Rico's Petroleum Industry

(In Thousands of Barrels per Day)

Products	Internal Demand	Refinery Capacity	Imports	Exports
Gasolines	35	95	-	60
Naphtha	170	20	150	-
Fuel oils and residuals	72	70	2	-
Distillates and miscellaneous	40	65	12	37
Total	317	250	164	97

Total Imports

Crude oil	250
Products	164
Total	414

Note that Puerto Rico's demand is not in balance with its refinery runs. This is mainly because of the large demand for naphtha to feed the chemical plants. Also, the economics of the refineries when established no doubt required a yield of product mix from the available crude oil that did not exactly match Puerto Rico's demands, with the excess to be exported.

3.1.2 Conditions in the United States Petroleum Industry

For many decades, the United States was self-sufficient in petroleum production and refining capacity, and restricted the import of "low-cost" foreign crude oil to about 12% of U.S. production. Refined products, except for residual fuel oils, were almost entirely prohibited. These restrictions were considered to be in the best interests of national security at the time because they were to foster a strong and expanding oil industry.

Restrictions on imports and subsidies to domestic oil producers seemed to accomplish the desired results, with U.S. crude oil production steadily increasing, until 1971 when a peak of just under 9.5 million barrels per day were produced. Since then, despite nearly unlimited production allowables by the regulatory agencies of the leading producing states, U.S. crude oil production is declining at a current annual rate of about 2%.

While the reversal of oil's growth rate is due primarily to economic and technical conditions rather than the insufficiency of the natural resource base, a return to a growth rate commensurate with that of demand is highly improbable even under changed conditions.

The best domestic U.S. prospects for new large-scale crude oil production provinces seem to be the Alaskan North Slope and offshore areas, offshore California, and offshore on the East Coast between Maine and Delaware. While it is probable that all of these areas will be intensively explored for oil and production discovered in the future, there will be considerable delay involved, so other sources of supply to meet U.S. petroleum demands must be developed for at least the next 10 to 15 years.

In contrast to the declining crude oil production trends, demand for petroleum products is constantly increasing and the increase has recently begun to accelerate. This process, which gives every indication of continuing at least for the next 10 years, caught the industry by surprise in 1972 and made all previous forecasts obsolete. As an example, the authoritative report of the National Petroleum Council, published in July 1971, projected total U.S. oil consumption of 26.0 million barrels daily for 1985; by June 1972 the Chase Manhattan Bank forecast that this level would be reached by about 1980; and, in late 1972, NPC's forecast was revised to show projected 1985 volume could be surpassed well before 1980.

There appears to be several reasons for this acceleration in oil demand:

1. The new restrictions in automotive emission levels require equipment and engine adjustments that increase the amount of gasoline required per mile of driving.
2. The industrial emission restrictions require refining practices that reduce the yield of gasoline per barrel of crude oil refined.
3. Oil is being called on to fill the gap created by shortages of natural gas and the delays of nuclear power plants.
4. There is a progressive substitution of fuel oil for coal-fired power plants because of the easier sulfur removal with this fuel.

The net result of these events is that the United States today imports 30% of its total petroleum consumption, and due to the divergent trends, this percentage is predicted to rise above 50% by 1980. This prediction allows for large production from Alaska by 1980 and some curbs on U.S. consumption. By that time, it is expected that over 10 million BPD will be imported, perhaps 4 million from Western Hemisphere sources (mainly Canada and Venezuela) and 6 million from the Eastern Hemisphere, mostly from the world's largest producing area--the Persian Gulf.

In addition to the shortage of crude oil, there is a shortage of refining capacity in the United States to convert the crude oil to useful petroleum products. This shortage of refining capacity is expected to become more acute with increasing demand in the near future.

While the importation of most finished oil products other than residual fuel oil was severely restricted under the Oil Import Control Program, the oil industry apparently expected that such importation limitations would be relaxed and the U.S. would allow product imports to increase substantially in the next few years. U.S. refining capacity has been virtually at a standstill despite the growth in oil products demand and the rapid decline in surplus capacity. With not a single new refinery project in 1972, much of the growth in demand in 1974 and 1975 will have to be met through imports of finished products.

This inevitable development is in direct conflict with the government's frequently stated opposition to the expansion of finished product imports. This opposition reflects the official view that the importation of finished products is tantamount to the exportation of domestic refining capacity which is held to be undesirable from a balance of payments as well as a national security point of view.

In recognition of this conflict, the government recently changed the import regulations to encourage new refinery construction as well as crude oil production. While foreign refined products will be allowed into the United States, they will have to pay a high license fee that should make them less attractive economically when compared with domestically refined products.

Probably as a result of these new regulations, plus clarification of the government's policies, there has recently been a marked increase in activity toward expanding U.S. refinery capacity. As it is the easiest, the first efforts are in expanding existing refineries, but in addition a number of new grass roots projects are being actively pursued.

A major obstacle to the construction of new refineries anywhere in the United States is the apparent shortage of suitable and economical sites. This problem is made more acute by the opposition of environmentally oriented citizens and hastily enacted stringent anti-pollution regulations. This applies particularly to the East Coast, the major U.S. market area. Total East Coast oil demand is expected to nearly double by 1985 from its present 6.5 million barrels daily demand. The increase would be equivalent to the output of 24 refineries of 250,000 barrels per day each. While there are signs of some relaxation of environmental opposition and a less hysterical local government reaction as the serious economic implications are realized, there is very little likelihood that this number of refineries will be located on the East Coast. Thus, the region will have to continue to depend on outside sources for much of its oil demand. The traditional sources of refined products for the East Coast are all expanding in an attempt to meet the demand. Local refineries are being debottlenecked and expanded, Gulf Coast refineries are expanding, and new Caribbean refineries are being constructed or are in the planning stage. Some of these projects appear to be in the nature of short-range, high-cost stopgap measures, so there is an opportunity for new alternate sources of supply, particularly those that can be put into operation quickly.

One of the delaying factors in locating new continental refineries is the problem of providing adequate deep-water tanker terminal facilities.

The only practical and economical means of transporting oil over the 12,000-mile distance from the Persian Gulf to the United States is by very large crude oil carriers (VLCC's), i.e., tankers of 200,000 DWT and over. Presently no deep-water port for VLCC's exists anywhere on the U.S. East Coast or Gulf Coast, but there are plans for the construction of such ports on both coasts. On the East Coast, environmental opposition apparently had blocked the siting of both new refineries and deep-water ports, but the situation now seems to be changing. It is unlikely, however, that any East Coast super-port will be ready before 1975, and some industry leaders indicate 1978 at the earliest. Yet the economics of a refinery running on imported crude oil are directly related to the availability of VLCC's. Consequently, East Coast refiners are looking at sites outside this market where it may be easier to construct both super-ports and refineries as well as considering trans-shipment via smaller shuttle tankers, as is done in some European locations.

The economics of crude oil trans-shipment are not fully accepted in the industry, however, and it is probable that efforts will continue to be concentrated on establishing deep-water terminal facilities close to the using refineries.

At present, the most advanced deep-water terminal plans are located in the Gulf area. At least one facility, the LOOP project, is scheduled for start of construction this year. In addition, at least two others are in the advanced planning stage.

There are also projects being planned and apparently favorably considered on the East Coast. At least three such projects are being reviewed in Maine, one in New Hampshire, two in New Jersey, and one in Virginia. While not all can be expected to achieve operating stage, some certainly will.

Because of its strategic position, its ability to make sites and facilities available relatively quickly and cheaply through government action and because of the potential lower cost of operation, refineries located in Puerto Rico could capture a significant portion of this market. The exact amount will probably depend largely on the will of the government of Puerto Rico and the timing and procedure it uses to exploit the opportunity. If it wishes, it could realistically expect to capture at least a third of the market and possibly even more.

3.1.3 World Trends as They Affect Puerto Rico

The most important recent events and trends in world petroleum can be summarized as follows:

1. The Western Hemisphere, in particular the United States, is no longer economically self-sufficient in petroleum.
2. Diminishing crude oil reserves and rising production costs, together with increasing domestic consumption, have turned the United States from an oil exporter into an importer.

3. Similar trends in Venezuela are making Venezuelan oil less available and less price-competitive compared to oil from other sources in the traditional consuming areas of the Caribbean and the United States.

4. Sharply rising consumption with dropping crude oil production will soon make the United States the world's largest oil importer, with strong competition from other leading oil importers.

5. The largest importers of oil have been Europe and Japan, both long distances away from their producing supply areas.

6. Rapidly rising consumption in both these areas has led to the development of super-tankers of 200,000 DWT and larger, called VLCC's (very large crude carriers), in order to reduce transportation costs.

7. Most of the world's crude oil reserves are concentrated in the Middle East in the Persian Gulf area.

8. Of necessity, most of the increased imports of oil into the United States will have to come from the Persian Gulf in VLCC super-tankers.

The above developments will cause considerable change in the current world oil industry and present new opportunities for some and economic penalties for others. It is probable that entities which try to compete directly with either the United States or the other powers for petroleum supplies will be hurt economically. Those that can be incorporated into one or the other for supply purposes will be helped to some extent. Puerto Rico, by its geographical and political position, will be associated with the United States.

Figures 2 and 3 indicate conditions in the world oil industry. This shows the tremendous petroleum reserves in the Persian Gulf area and the great distances to the consuming areas. The importance of reduced transportation costs is obvious. Appendix D contains information on the present trend upward in the size of tankers under construction and on order, and the recent past and projected growth in the world tanker fleet and its composition. Of importance in the Appendix D information is the fact that ocean transportation costs in 200,000 DWT vessels are approximately 54% on an average of the cost in 60,000 DWT tankers, and the percentage drops to 48% if 300,000 DWT ships are used. These lower costs are the reason for the present emphasis on building VLCC's.

The significance to Puerto Rico in all this is that, on the one hand, it runs the risk of being competitively squeezed because of the changes occurring in the world industry, but, on the other hand, it is in a good position to compete for markets if it should so wish.

In order to compete, it must have the tools, including port and terminal facilities for VLCC tankers and petroleum refineries to supply a base for its own industry along with products for export. A ready-made and almost tailored market for produce exists in the U.S. East Coast area, a natural market for Puerto Rico.

By exploiting this market, Puerto Rico can assure itself of petroleum products for local consumption at very favorable prices. Considering the growing proportion of energy supplied by oil imports in the United States and almost all industrial nations, Puerto Rico, which has always had to import its main energy source, will no longer be competitively disadvantaged from this cause. Further, by becoming a vital supplier of part of the U.S. oil requirements, Puerto Rico will assure protection for its own supply.

3.1.4 Future Expectations for Puerto Rico

3.1.4.1 Puerto Rico's Need

To improve employment opportunities and social conditions for its people, additional industrial activity is needed. The petrochemical industry offers a base for industrial development. Many corporations have located petrochemical plants in Puerto Rico based partly on the ready avaiability of naphtha from Venezuela and the Antilles. The unprecedented increase in world demand and price for naphtha has made these sources of supply questionable. The existing industry in Puerto Rico, therefore, is hit with an economic restraint that needs correction. Further, it is reasonable to assume that new petrochemical facilities could be attracted, and the owners of existing plants could be influenced to expand, if there were a dedicated and economic source of unfinished naphthas in Puerto Rico for processing into feedstocks. This need not necessarily be from sources on the island, but the most secure source and probably the cheapest would be from building and operating additional Puerto Rican refinery capacity. Greater refining and petrochemical capacity would involve greater needs for electric power production. These would require greater imports of crude. The increased economic activity would generate needs for additional fuel for motor vehicles, for service industries, and conceivably fuel for additional plants and further downstream processing into consumer goods of the raw petrochemical products.

The existing pier facilities in Puerto Rico for unloading crude oil and petroleum products are definitely limited to smaller size tankers. The composition of the world tanker fleet is changing rapidly in the direction of larger vessels because of the economics involved, especially on long-haul routes. It is estimated that by 1980, 70% of total tanker tonnage will be tankers larger than 200,000 DWT,* compared with the 70,000 DWT maximum that can be accommodated at only one of the Puerto Rican refineries. The ability to receive increased crude requirements for the desired volume of future industrial activity at the lowest laid-down cost is most necessary to maintain Puerto Rico's competitive advantage. Therefore, facilities for berthing and unloading these very large crude carriers (VLCC's) would be needed, together with means of transporting the crude to the new refinery facilities. Ideally, it would be desirable for any new refining capacity to be located close to any new deep-water unloading terminal, and for the additional petrochemical plant capacity to be sited close to the new refineries for economical movement to them via short pipelines of the numerous types of feedstocks which the refineries would derive by "pre-processing" of the unfinished naphthas they would produce. This would be in line with the policy being followed in other developing petroleum/petrochemical complexes such as the one at Rotterdam and, in fact, the one in the Guayanilla area. In addition, any future fossil fuel power stations would preferably be located close enough to the refineries so they could be supplied with residual fuels by short pipelines. In practice, some modification of the ideal planning may be necessary for environmental or social reasons as well as the need to care for the future needs of the existing installations.

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* The Economics of Deepwater Terminals, Maritime Administration, U.S. Department of Commerce, 1972, pp. 6-7.

To increase refinery capacity to exactly match Puerto Rico's needs for the various kinds of products would not be feasible. Puerto Rico's product demand mix does not conform to reasonable refinery product yields and thus some excess products are necessarily produced in order to satisfy the need for others. Further, the product mix would be changing, at least to some extent, from year to year as the complex developed. Hence, to avoid importing any products whatever, some excess refining capacity would be required, and significant quantities of some products not needed in Puerto Rico would be produced and could be exported. As noted previously, the United States is facing a deficit of oil products and could absorb any excess from Puerto Rico. Such exports would be good for the economy of the facility and, if a market for larger exports were assured, it would be still better with a broader base furnished for carrying the costs of a deep-water terminal, if plans were made for an even larger capacity refinery installation. The current petroleum energy deficiency in the United States indicates that supplies from the Southern Atlantic and Caribbean islands, if available soon enough, will find a market.

3.1.4.2 Growth Projections

The increase in Puerto Rico's consumption (including unfinished oils such as naphthas to be converted into petrochemicals) has risen in the past six years at the rate of about 17.5% per year, but it is not expected to continue. Two projections of future consumption have been furnished, one intended to be extremely conservative, with a growth rate of 5% per year compounded annually. The other, an "optimistic" forecast, is based on continuing the current efforts to increase petrochemical capacity, with consumption continuing to grow at a rate of about 16% and then gradually tapering off to a rate of 5% per year in 1990.

For the economics of this study, a compromise between these two has been assumed. This "compromise" projection recognizes that some of the problems holding back the development of wholly safe and ecologically satisfactory nuclear power plants will be successfully overcome, thus reducing the need for increasing large quantities of heavy fuel oil. The total requirements of all products, including the unfinished naphthas required for petrochemical feedstock production, are plotted in Plate 1 which shows the "conservative," "optimistic," and "compromise" projections.

A breakdown of the principal refinery products for the "compromise" forecast is given in the following table.

Projected Internal Demand
(In Thousands of Barrels per Day)

	Present	1975	1980	1985	1990
Consumer products	75	115	150	201	252
Fuel oils and residuals	72	97	144	150	152
Industrial products including naphtha	170	288	376	549	746
Total	317	500	670	900	1,150

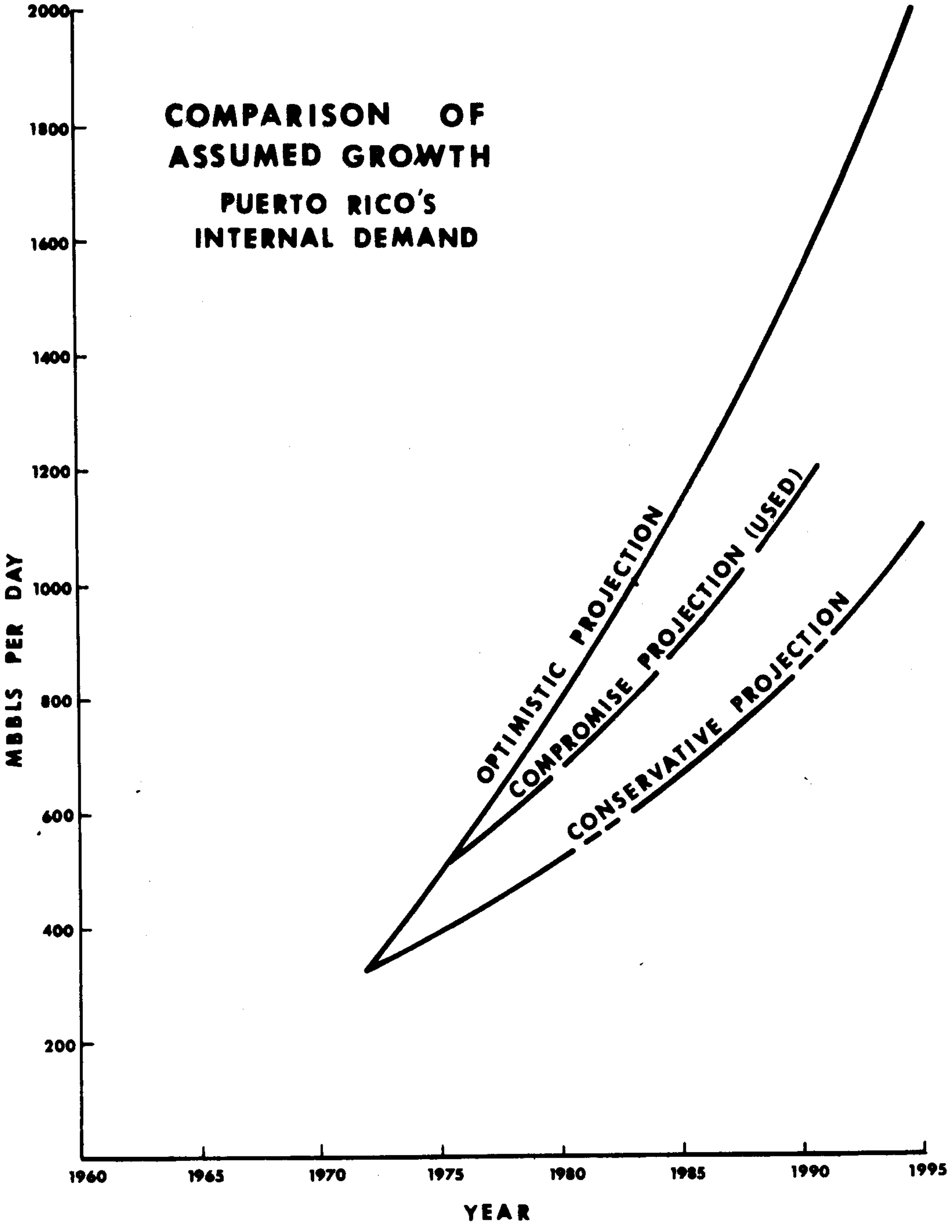
COMPARISON OF ASSUMED GROWTH
PUERTO RICO'S INTERNAL DEMAND
2000
1800
1600
1400
1200
1000
800
600
400
200
MBBLS PER DAY
OPTIMISTIC PROJECTION
COMPROMISE PROJECTION (USED)
CONSERVATIVE PROJECTION
1960
1965
1970
1975
1980
1985
1990
1995
YEAR

PLATE 1

3.1.4.3 Four Cases for Analysis

Of the numerous possibilities for satisfying Puerto Rico's petroleum product requirements and to assist with activity by increasing production of petrochemicals as described in the site screening analysis, four basic cases designated A, B, C and D have been assumed as a basis for study. For each case, several optional sites were viewed as possibilities, but those which had obvious disadvantages for one good reason or more were screened out, and only the remainder were thoroughly investigated. The important features of each case are described below.

Case A

This is based on no increase in present refining capacity in Puerto Rico, and on importing the necessary amounts of each product to supply the increasing deficiency between the growing future demand and the fixed portion of this demand that would be furnished by the local refineries. Within Case A, two basic site philosophies were studied, viz.:

1. Constructing five separate product import terminals, three to be sited at San Juan, Ponce and Mayaguez, for the handling of consumer products, and the others for handling fuel oils and petrochemical feedstocks at Guayanilla and Guayama.
2. A large central product import terminal, with distribution facilities to the centers of the major consuming areas, and secondary distribution therefrom by the private corporations involved.

Two assumptions can be made for determining the amount of product required for import. One is that present export commitments of existing refineries must be maintained; the other that the exports will be curtailed to meet local requirements first, thus reducing the import requirements. The net amounts to be imported in barrels per day are:

	Assumption #1	Assumption #2
1975	185,000	90,000
1980	355,000	250,000
1985	585,000	500,000
1990	835,000	750,000

Note that there would only be a significant difference in the effect of the two assumptions in the early years. Since this is the case and since the existing refiners would probably find difficulty in breaking their export contracts in the early years, we have used assumption #1 for analysis.

Case B

The main assumption is that the existing refineries would be expanded in direct proportion to their existing capacities so that the importation of any products, including petrochemical plant feedstocks, would not be necessary. As mentioned in 3.1.4.1, to completely supply the rather unusual product mix required in Puerto Rico, which would be changing as the petrochemical industry developed further, would require refining capacity and refinery runs significantly greater than if the yields were such as to exactly match the demand for each product. Hence, in Case B, there will be quantities of some kinds of products available for export. It has been assumed that existing facilities for exporting products which are surplus in the present refining program would remain in serviceable condition because of their second duty of unloading crude, but that new product export facilities would be required sufficient to handle the additional imbalance as refinery runs increased. Within this case, two basic philosophies were studied, viz.:

1. Each refinery's pier and crude receiving and storage facilities would be expanded as needed to handle the increasing volumes of crude to be processed. However, the expanded installations would not provide any increase in tanker size above the sizes presently being handled.
2. A large central crude oil terminal for importation of all crude in excess of the volumes presently arriving at the three refineries. The terminal would accommodate tankers of at least 200,000 DWT and would have facilities for temporary storage and systems for distributing the crude as needed to the three refineries.

Case C

In this case, there would be no expansion of the three existing refineries, but one or more entirely new refineries would be built as needed to produce all of Puerto Rico's domestic requirements, including all petrochemical feedstocks. Total refining capacity and output would be the same as in Case B, with the surplus of some products due to imbalance between yields and demand being equal to the corresponding volumes of Case B. All crude oil requirements in excess of volumes presently being imported by the three refineries would be unloaded at a new large import terminal for handling tankers of at least 200,000 DWT. Several terminal sites were investigated, with the additional assumption that the new refining capacity, substantially all new petrochemical plant capacity, and all new fossil fuel power plants built after 1978 would be located close to the terminal--all these for the economic reasons outlined in 3.1.4.1. However, some sites which appeared to have superiority for berthing and unloading the tankers were known to be undesirable from a social and/or ecological standpoint for construction of the associated refinery, petrochemical and power plant complex. For these, although it might be possible to locate the complex away from the terminal, to be supplied by a connecting crude pipeline system, no costs were developed for this preliminary screening study.

Case D

With one exception this case is exactly like Case C. The exception is a greater capacity for unloading crude, for refining it, and for exporting products. It is basically Case C, refining capacity to serve primarily Puerto Rico, with additional export refining capacity. The basic reasoning behind this case is that there is a scale effect to terminal and refinery operations that will substantially reduce the unit cost of products for local consumption as the size of the facility increases. Therefore, if a substantial export market can be found, the locally consumed products could be "piggybacked" for lower incremental costs than would otherwise be the case. Such a market appears to exist in the continental United States at this time with potential growth for the foreseeable future.

3.1.5 Future Facility Requirements

3.1.5.1 Refineries

Case A, as noted in 3.1.4.3, is based on not installing any additional refining capacity in Puerto Rico. In the other three cases, considerable increases in refining capacity would be made. For the sake of simplicity, all the capacity figures are stated as "net" capacity or salable production, and do not include refinery fuel or losses.

The optimum mix for the new refinery facilities is impossible to determine within the time frame of the site screening study. The determination of the most advantageous mix of products to be processed from a barrel of crude oil depends on the crude oil that is being used as a feed to the refinery unit, on the potential market, on the costs of both crude oil and product, transportation costs and other factors. For the site screening study, the exact product mix is not necessary to determine at this time. What is required is an approximation of the product mix and, in particular, a summation of those products that will be absorbed within Puerto Rico that can be expected as refinery yield from a total barrel of crude oil. From this will also be determined the surplus products that would be available for export. We have assumed that in both Cases B and C new refinery capacity will be constructed to yield 50% in the form of naphtha, fuel oils and residuals that will be fully absorbed in Puerto Rico. The remaining products consisting of gasolines, distillates and miscellaneous will be partly absorbed in Puerto Rico and partly exported. Considerable variation from this assumption might be expected depending on the economics as analyzed by each prospective refinery and as influenced by restrictions imposed by the Commonwealth government. We believe that our assumptions are reasonable, however, and will result in a valid basis for analysis for site screening.

The assumptions for Case D are that the new refineries will be basically the same as those for Cases B and C to serve Puerto Rico but, in addition, will be built with the full range of products to serve export markets. It is not important for our site screening study what the mix of these export products might be. Our analysis assumes that facilities will be provided for importing the forecast amounts of crude oil and exporting all products in excess of domestic needs. Case D could very well turn out to be close to an optimum mix of products. Note that with certain crude oils and certain market conditions the assumed refinery mix for Case C might be off enough to require refining capacity equivalent to that developed for Case D. We want to emphasize that we are not advocating any particular case as the ideal for Puerto Rico, but merely assuming these cases to assist in the analysis for site screening and planning of the prospective facility.

Based on our foregoing assumptions and analysis, we derive the following additional refinery capacity requirement for the future in Puerto Rico.

Assumed New Refinery Requirements

	Cases B and C To Serve Primarily Puerto Rico	
	Capacity (BPD)	Surplus for Export (BPD)
1975	500,000	250,000
1980	800,000	380,000
1985	1,150,000	500,000
1990	1,600,000	700,000

Case D To Serve Puerto Rico, Plus Export

	Capacity (BPD)	Export (BPD)
1975	1,000,000	750,000
1980	1,800,000	1,380,000
1985	3,000,000	2,350,000
1990	3,600,000	2,700,000

New refineries or any expansion of existing refineries would be designed and constructed in accordance with all current laws and regulations so that minimum ecological and other environmental disturbance would result, by making use of applicable modern anti-pollution technology. In addition, particular attention would be given to safety features.

3.1.5.2 Terminals

The petroleum terminal consists of tanker berths, oil discharge and loading systems, a tank farm, and various support facilities such as service craft harbor, administrative facilities, shop and storehouses, firefighting systems and anti-pollution systems. In addition, it is desirable to have an anchorage for ships awaiting berth. A source of power, fresh-water supply, communications and housing for the work force must be provided if existing installations are inadequate.

Information on petroleum terminal design covering piers and other equipment requirements, operation and safety is given in Appendices D, E and F.

It has been assumed that in the design of such a terminal there would be full compliance with all current laws and regulations concerning minimization of ecological damage and avoidance of pollution and other environmental damage. In addition, full attention would be given to safety.

Required Number of Tanker Berths--The number of berths required has been derived from the assumed refinery crude oil demands and product movements, using simplified assumptions as to tanker size, turnaround times and berth occupancy rates. While not precise, this analysis is believed to be reasonable and adequate for a screening study.

Assumptions:

Berth occupancy: 50%

Product ships, average size:

30,000 DWT at present

40,000+ DWT by 1980

60,000 DWT by 1985 onward

Crude ships, average size:

100,000 DWT at present

150,000 DWT by 1980

200,000 DWT by 1985

250,000 DWT by 1990

Approximate turnaround time is assumed to be:

For ships up to 100,000 DWT--24 hours
and for 200,000 DWT--36 hours

In some cases, the number of berths calculated in the above assumptions has been adjusted slightly.

For Case A--Puerto Rico's future expansion of product demand imported.

Year	Assumed New Product Demand (BPD)	Required Berths
1976	90,000	2
1980	250,000	3
1985	500,000	4
1990	750,000	5

For Case B--Crude oil imported to meet expansion demands of existing Puerto Rican refineries.

Year	Assumed New Crude Oil Demand (BPD)	Required Berths
1976	500,000	2
1980	800,000	2
1985	1,150,000	3
1990	1,600,000	4

Note: Existing refineries will need new product export berths.

For Case C--Crude oil imported for new refining center to serve Puerto Rico's needs and with excess products exported.

	Assumed Crude Oil Import		Assumed Products Export	
Year	BPD	Berths	BPD	Berths
1976	500,000	2	250,000	2
1980	800,000	2	380,000	3
1985	1,150,000	3	500,000	4
1990	1,600,000	4	700,000	4

For Case D--The same as Case C, but with a large export refinery added to improve scale factor.

Year	Assumed Crude Oil Import BPD	Assumed Crude Oil Import Berths	Assumed Products Export BPD	Assumed Products Export Berths
1976	1,000,000	4	750,000	8
1980	1,800,000	6	1,380,000	10
1985	3,000,000	8	2,350,000	14
1990	3,600,000	8	2,700,000	14

Required Terminal Tank Farm Capacities--The purpose of the terminal tank farm is to smooth out the variable oil flow from tankers either discharging or taking on cargo. Because of the arrival pattern of the ships, and the fact that they are only discharging or taking on cargo for a fraction of the time they occupy a berth, the flow into or out of the terminal on the marine side is highly erratic. At the same time, because the process rate must be kept nearly constant, there is a comparatively steady flow into or out of the terminal on the land side. The tank farm smoothes the difference, in effect acting as a surge reservoir.

The terminal tank farm is thus purely an operating facility and not storage. Storage, for either inventory reasons or strategic security, is another matter. A storage tank farm can be located outside the terminal area and is often located near a refinery. The location of storage tankage at this facility will depend on the size needed and on the availability of land at the location considered for either the terminal or the refinery.

For terminal operations alone, the capacity of the tank farm is determined largely by the size of the ship and the arrival pattern. Secondary influences include the volume of terminal throughput and the pattern of different products handled and segregations required that limit the interchangeability of tanks. The methods of terminal operation also play a part, especially such factors as whether or not measurement of oil handled is by tank gauging or direct metering.

The sizing of an optimum terminal tank farm is a complicated and involved analysis. Even if it were possible at this stage, it is not warranted for a site screening study and therefore simplifying assumptions have been made.

For comparative pricing and site evaluation purposes, terminal crude and product tank farm capacities were assumed to range from about ten times the daily average for the lower throughputs down to six times for the cases with extremely high volumes.

Assumed Terminal Tank Farm Capacities

	1976	1980	1985	1990
Case A				
Products imported, BPD	90,000	250,000	500,000	750,000
Products tank farm capacity, MMB	0.9	2.5	5.0	7.5
Case B				
Crude oil imported, BPD	500,000	800,000	1,150,000	1,600,000
Crude oil tank farm capacity, MMB	5.0	7.0	12.0	14.0
Case C				
Crude oil imported, BPD	500,000	800,000	1,150,000	1,600,000
Products exported, BPD	250,000	380,000	500,000	700,000
Combined tank farm capacity, MMB	5.5	9.0	13.0	17.0
Case D				
Crude oil imported, BPD	1,000,000	1,800,000	3,000,000	3,600,000
Products exported, BPD	750,000	1,380,000	2,350,000	2,700,000
Combined tank farm capacity, MMB	13.5	22.0	32.0	38.0

3.1.5.3 Distribution Systems

To conduct the refined products to the Puerto Rican users from the new product import terminal or new refineries, new and expanded distribution systems would be required. Existing systems include an industry owned and run products pipeline from Guayanilla to San Juan as well as a barge system and tank trucks over the road.

Determination of the optimum product distribution system is a complicated exercise with many variables. Such an analysis is beyond the scope of this study and is not needed to evaluate and compare sites. It is sufficient to assume a reasonable system and compare the relative costs and impacts of its construction and operation.

For purposes of site screening, we have made several assumptions for identifying, evaluating and comparing the distribution systems for each case from each site:

1. The existing distribution systems are assumed to continue in operation as at present.
2. New systems will be required for the increased product demand.
3. The new systems will utilize all three modes of transportation, e.g., pipeline, barge and tank trucks.
4. In each case considered, the cheapest transport mode will be assumed for each product to each destination.
5. The products to be distributed are to be classified into three broad categories:

a. Consumer products, generally assumed to be "clean" such as gasoline, LPG, kerosene, etc.

b. Unfinished naphtha for petrochemical plant feedstocks (could go through a clean product or consumer pipeline).

c. Heavy fuel and other "dirty" products which must be heated and are only economically practical for pipeline transportation over short distances.

6. Fixed installations for the new systems, i.e., pipelines and terminals, will be financed and operated by the government whereas mobile facilities, such as trucks and barges, will be owned and operated by private companies to suit market needs.

7. Financial analysis for comparison will include the "for hire" tariffs of the trucks and barges to derive a total comparative delivered cost at the consuming center.

8. Consumer products are analyzed on the basis of delivery to the three major cities of San Juan, Ponce and Mayaguez with apportionment on the basis of population.

9. Naphthas are assumed to be distributed to existing petrochemical plants on the basis of present need.

10. New petrochemical plants are assumed to be constructed close to the new refineries with direct piped delivery.

11. Heavy fuels are assumed to be delivered to existing and announced thermal power plants on the basis of making up for deficiency of supply from existing refineries.

12. Future power plant expansion, beyond present announced plans, is assumed to be near the new refineries to take advantage of the supply of residuals and pitch fuel that cannot economically be piped long distances.

Based on the above assumptions, systems were developed and sized for preparing comparative cost estimates.

3.2 Dry Bulk Cargo Requirements

3.2.1 Current

There are no present requirements in Puerto Rico for deep-draft, dry bulk shipping. Any new requirements would depend on development of new industry.

3.2.2 Potential Industry Users

In the site screening procedure, consideration was given to suitability for other possible port facilities in addition to the petroleum terminal and associated refinery and petroleum-related industrial complex. These other facilities would be for handling dry bulk cargoes, for special types of vessels, "general" port facilities for conventional freighters and passenger vessels, and miscellaneous facilities such as a shipbuilding and ship repair yard. The possibilities of requiring these facilities are based for the most part on the findings in a study of port-related industries prepared by Arthur D. Little in 1960. We have made a brief appraisal of the present-day likelihood of developing such facilities, and of their suitability for including them with the deep-water petroleum port. For those sites which could accommodate some of these other facilities, the latter have been included in the preliminary port development layouts in this study.

3.2.2.1 Agricultural

Bulk agricultural commodities include sugar, wheat, corn and rice. Sugar exports at a little over 100,000 tons per year are declining. The other commodities, ranging around 150,000 to 160,000 tons per year, are imported. Even if these amounts double or triple in the future, bulk shipments are not likely in vessels over 20,000 DWT. Such ships can therefore be accommodated in most general cargo harbors. Unless a new general harbor were to be developed, facilities for agricultural shipments should be concentrated in San Juan, Ponce and Mayaguez, the greatest centers of consumers, where a large new petroleum port could not be located.

3.2.2.2 Metallurgical

Deep-draft bulk shipping for metallurgical cargoes means primarily iron ores and pellets. Coal, coke and non-ferrous ores are usually either carried in smaller volumes or are of a density that does not result in deep draft. There would be no need for such port facilities without a using industry, such as a mining operation, or a metallurgical plant.

There is a possible economic case to be made for a steel mill in Puerto Rico using imported ores and coking coal and local limestone. The greatest drawback to such a plant at present is its pollution potential. While, like oil refineries, modern steel mills are much cleaner than those of the past, they are still major pollution sources. This is particularly true for air pollution. The potential for a metallurgical plant has been examined at each site, with full consideration given to its air pollution potential.

Iron ore carriers and combination tanker-ore carriers are being built of VLCC size. This trend will continue. Such ships are particularly attractive for the Japanese trade, where quantities are large and distances are great.

For a Puerto Rican mill, it is not likely that such behemoth ore carriers will be required. We can only speculate at this time as to the mill that might be built, but do not believe it would be large because the transportation costs for bringing in raw materials when added to the costs of delivering export products would tend to prevent competitive pricing of the latter. Arthur D. Little forecast 90,000 tons of ore and 54,000 tons of coal per month in its 1960 study. Even if this were doubled or tripled, two or three ships per month in the 150,000 DWT class would be more than enough. Iron ore is being imported to the U.S. East Coast from South America, and this could be the ore source for a Puerto Rican mill. If some of the vessels carrying ore to the United States were to bring coking coal from Chesapeake Bay to Puerto Rico on their return to South America for another load of ore, there would be considerable reduction in the cost of bringing in the coal. Another possibility of reducing coal transport costs would be the use of combination tanker-bulk carrier vessels to carry export petroleum products to the U.S. East Coast, and return with coal.

There is a possibility that petroleum coke might supply some of the steel mill's requirements. If steel-making technology advances to the point where reduction of the iron ore without coking coal is economically attractive, a Puerto Rican mill would be even more feasible.

Considering the probable volume and the probable sources of ore in South America, we believe bulk unloading facilities for ships 60,000 to 150,000 DWT would be satisfactory. This requires about 60 to 65 feet of water depth, similar to the oil product export tanker facilities.

Coal or coke ships and other ore carriers, including copper ore ships, could use the same facilities. If two berths were installed, capacity would be more than adequate for any conceivable demand known to us at this time.

The facilities for discharge would require traveling unloaders on the piers, plus either trestle-supported conveyors or overhead bucket tramways to shore. The same facilities could be used for all cargoes with suitable diverters, reclaimers and scrapers.

For loading, if required, special loading devices are necessary. Adapting loading chutes to the receiving unloader hoppers would allow dual function. The same conveyor system could be designed for two-way usage.

3.3 Special Cargo Requirements--Unitization

3.3.1 Introduction

General cargo is currently transported at sea and handled in port in two basic forms, namely break-bulk and in unitized standard packages. The diversity of shape, weight and size which characterizes general cargo has in the past made it reasonable to handle and stow such cargo manually on a break-bulk basis. However, with the advent of mechanical handling equipment and the use of standardized box transport in the truck and railroad industries, development has rapidly come about of unified container system concepts in the general cargo shipping industry. Containerization is the most developed form of unitization and as such is suited only to the most developed industries and systems.

A comparison of the traditional general cargo transport-handling system and containerization leads to the conclusion that the latter is less labor-intensive and more capital-intensive. In addition, containerization usually depends on land transport modes involving modern truck and/or rail systems, which must be effectively integrated with port transfer systems and high-speed container ships. Where highly developed land transport modes are not economically feasible and/or where cargo is not shipped in large quantities to single destinations, the concept of containerization usually is not economically feasible. The objective of containerization is to achieve optimum advantages of the through-movement of cargo, without rehandling, from the shipper's platform to the consignee's receiving platform.

3.3.2 Containers

Like the rest of the world, much of Puerto Rico's general imports and exports are handled in containers. This trend can only continue to grow.

As the economy expands, this traffic will also. If it grows sufficiently, super container ships with lengths and breadths similar to VLCC tankers may be put into service. Such ships, with high speeds, are already coming into existence, especially for the United States to Europe high-density trade. As with any other bulk cargo, if the volume is sufficient to fully utilize the ships, there is a saving by increasing size. The possibility would be most important for any island economy like Puerto Rico's.

The super container ships have the horizontal dimensions of VLCC's, but not the draft. Because of the lower density of cargo within a fully loaded ship, container vessels have comparatively shallow drafts. Current studies indicate a port depth of 40 feet will be ample for such ships in the foreseeable future. Thus, such ships do not need a deep-water port.

Ordinarily, it would be recommended to develop such facilities in the three existing ports with the greatest populations. However, there are some limitations on both available land and practical water depths at existing ports and, therefore, container-ship facilities have been examined at each of the deep-water port sites. Such facilities are not normally recommended at a petroleum industrial port, but might prove attractive in view of existing port limitations.

Facilities required include a full face wharf with a length of about 1,200 feet for each ship. Special high-capacity handling cranes for removing and placing the boxes on the ship are required at the wharf face. Immediately behind the cranes, a clear apron of 100 feet is required. Also, either parallel to the wharf or inland from it, an area of about 500,000 square feet per berth is required for stacking, storing and sorting boxes. It is presumed that facilities for stuffing and unloading the containers will be located away from the port area.

Container-ship berths require still water during lifting and placing of the cargo containers. Where natural features do not afford sufficient protection during ordinary weather and moderate storm conditions, a breakwater would be necessary.

In addition to the port facilities, a first-class truck highway system is required to connect the port with the users.

3.3.3 LASH

The "lighters aboard ship" (LASH) system of shipping has been determined by previous investigators to be not economically feasible or attractive in the Puerto Rican trade. We confirm this conclusion because of the lack of need for major lighter and barge distribution. Containers do the job as well and cheaper. Should such vessels occasionally call, they can be accommodated in other port facilities.

3.3.4 RORO

"Roll on/roll off" (RORO) and trailer ships are used and will continue in service. To some extent, such vessels compete with container shipping systems. Generally, as volumes increase, they become less efficient as compared to container shipping systems. We do not expect frequent arrivals or large vessels of this type in Puerto Rico. Since such ships are of shallow draft, even less than container ships, they do not require a deep-water port.

3.4 Miscellaneous Port Facilities

3.4.1 Service Harbor

In addition to the tanker berths, a harbor for tugs, pilot launches, work boats and service craft will be required on the adjacent shore area. This harbor should be large enough to accommodate all of the required service craft together and give complete protection against storms, including hurricanes. The location of the small craft harbor should be close enough to the deep berths and their approaches to avoid long trips back and forth to the main berthing area.

Offshore island sites and other remote sites will probably also have to include freight handling and passenger launch or ferry facilities.

In some cases, the service harbor can be expanded into a general small port for ocean freighters and similar vessels. It also is possible to include the service harbor facilities in a general port.

Without the inclusion of ocean freighters, the service harbor should have a depth of about 20 feet. Dolphin berths with water and possible fuel connections for the required number of tugs, including allowance for doubling up, should be provided. Slips for the number of launches to be used should also be provided in the more sheltered part of the harbor. A bulkheaded marginal wharf, 300 to 400 feet long with a paved area at least 50 feet wide, should be provided for work and possibly freight barges.

The general configuration of the harbor, especially the breakwater, should take into account the natural features of the shore. A cove of the proper depth enclosed by a spit of land to act as a breakwater would be ideal as a base for development. If this is not available, taking advantage of reefs and shoal areas both reduces cost and minimizes interference with the natural flow of water.

3.4.2 Possible General Port

A general port is not an integral part of the deep-water port development. However, there may be the possibility of such a development at some locations. The general port could be formed by expanding and providing a deeper service harbor. Breakwater protection and a minimum depth of 30 feet are recommended for the general port. This depth is not necessary all over the harbor, as depth in the service craft area could be 20 feet.

The general port should include marginal wharves having about 600 feet of length per berth provided with unobstructed paved aprons at least 100 feet wide. Depending on the cargo that might be handled, transit sheds of another 200 feet in width could be provided behind the aprons. If the cargo requirements are uncertain, the sheds could be deferred but space should be reserved for them.

Passenger ships could also be accommodated in the general port. None of the sites selected seems likely to attract a large amount of this traffic, so special facilities are not recommended. Passenger ships could be accommodated at the normal freight wharves on an occasional basis.

It is also possible to incorporate general port facilities in the container-ship harbor and in the bulk cargo harbor, if one is provided. Greater water depth would then be necessary. Depth of 40 feet for containers and 60 feet for bulk cargo vessels are recommended. Care must be taken in the case of the bulk cargo combination to avoid other cargo contamination from bulk materials blowing across berths.

3.4.3 Shipbuilding and Repair

While this is a port-related industry, it is not normally considered an integral or necessary part of a deep-water industrial port, especially not a port for petroleum. There is inherently some conflict of use in the two operations, although it is perfectly feasible to conduct both in the same port with proper planning and spacing of facilities. The one advantage of having both operations in the same port is that the existence of petroleum processing facilities gives the potential for cheaper, more efficient and safer tank cleaning of ships preparing for drydocking and hot repair work.

There would be an advantage to locating a shipbuilding yard close to a steel mill with heavy plate rolling capability although, in view of Puerto Rico's size, this advantage of proximity is not an overriding one. In fact, we think this would be the most realistic, economic basis for a shipbuilding operation in Puerto Rico.

A shipyard, if it were included, would require more shore frontage than either a petroleum port or a dry bulk cargo port. The shipyard requires building ways or docks, repair drydocks, fitting-out piers and other waterfront development. It would not be a significant air pollution source. The empty ship draft of ships in the VLCC class would require a water depth of only 40 feet.

The suitability or non-suitability for a shipyard of any of the sites investigated has not been included in the site screening criteria of this study.

If a shipyard is seriously planned for Puerto Rico, we recommend intensive investigation of the possibility of incorporating it with the large graving dock at Roosevelt Roads Navy Yard.

3.5 Land Requirements

3.5.1 Port and Berthing Area

Except for the special cases of dredging a basin inland at Arecibo and at Jobos, it is assumed no land would have to be acquired for the main berthing areas themselves. At all other locations, the berths would be either offshore, or in a natural embayment, outboard of the normal shoreline. This holds true for both petroleum tanker berths and other deep-draft berths.

3.5.2 Service and Foreshore Area

At most sites, some foreshore area would be required for right-of-way submarine pipelines or trestles to the berths and for a service craft harbor and service area. This is generally a small tract of a few acres. For simplicity, it is assumed in most cases that this area could be incorporated in the tank farm or other port area requirements.

3.5.3 Tank Farm Area

The land requirements for the tank farm depend on its size; the number, size and type of tanks; the spacing and buffer zone criteria used; the spill containment provisions; the pumping and metering stations installed; and the ballast water storage and treatment facilities. Considerable variation in area requirement is possible. Striking a reasonable balance and to allow some future flexibility and growth, we are assuming a requirement of 500 acres for the terminal tank farm. For Case A only, in view of the lesser volume probable, we have reduced this to 200 acres.

The terminal tank farm would ideally be located as close to the petroleum berths as possible. The soil conditions could be rather poor, either marshy or hilly. However, where bearing capacity is low, construction costs of tankage would be increased considerably. There is an advantage for the export tanks to be elevated to allow gravity loading of ships, but this is not essential.

If the land is low, it should be protected from flooding from either rivers or storm surge from the sea. In this case, a special rainwater drainage system with pumps would be required. In any case, the drains would be provided with oily water separators to prevent pollution.

3.5.4 Dry Bulk Storage Area

The land requirements for receiving and handling dry bulk materials depend on the materials to be handled, the clearance for segregating different materials, the throughput volumes, the size of delivery ships and the materials handling equipment. For this study, we have arbitrarily assumed 200 acres to serve two berths. This assumes actual storage at the plant site and materials at the port will be moved in and out quickly. It also assumes contiguous other port operations so that facilities might be shared.

The type of soil and land terrain is more critical than with a tank farm. Ideally, the bulk material storage area should be close to the berths and oriented so that conveyors and similar systems from the ship are straight. A marginal wharf arrangement is ideal, but not always practical. The land should be relatively level and not too much above ship deck height. Depending on the nature of the material, it may not be necessary to protect the stockpiles from flooding, but they should be protected from water erosion.

In some cases, protection against blowing wind might be required. The bearing capacity of the soil could be critical, depending on the density of the material handled. Typically, iron ore piles give great trouble with deep-seated slide failures and lateral plastic creep. Non-plastic soils are preferred. Plastic soils are usable, but require special precautions including pile height limitations, which might require more land area.

3.5.5 Cargo, Containers and General Storage Area

The basic requirement is level land, reasonably protected from flooding. Since we have no data on which to size the land requirements, we have assumed 100 acres, usually contiguous with the dry bulk area.

3.5.6 Petroleum Industrial Area

The area for new refineries and petrochemical plants could vary widely. We have assumed 1,500 acres for Case C and arbitrarily doubled it to 3,000 acres for Case D. This is based on opinion expressed by authorities of several major oil companies that they would not be interested in a site for a major grass roots refinery and petrochemical complex today unless it had at least 1,500 acres available. Admittedly, this includes land for a tank farm, major offsites, a good buffer zone, pollution abatement facilities and room for expansion. It is probable that this area could be reduced somewhat, particularly for a single refinery, but we believe it prudent to target this amount of land for future flexibility and to allow consideration of multiple refineries sharing the same offsite facilities.

The land should be reasonably level, protected from flooding and well drained. Sites with soils requiring piling or subject to consolidation and foundation settlement are naturally much less desirable than those with strong stable soil.

3.5.7 Metallurgical Industrial Area

It is uncertain what facilities of this type can be attracted to Puerto Rico, so land requirements are difficult to define. The study of port-related industries prepared by Arthur D. Little in 1960 indicated the possibility of a steel mill requiring 300 to 500 acres and an aluminum smelter with 150 to 300 acres. There also seems to be the possibility of a copper refinery. To assist with the screening of a site, we have assumed that the petroleum industrial land requirements were of primary importance and would be satisfied first and then available land examined for metallurgical industries. We have assumed the maximum required for metallurgical industries as 1,000 acres. The type of land should be the same as for the petroleum industry except there is less tolerance for hilly conditions.

3.5.8 General Industrial Area

We have not assumed any specific land area for general industrial purposes. No doubt some will be required, but the amount can wait future definition. The existence of extra land for this purpose is a favorable factor for site selection.

3.6 Ancillary Services

3.6.1 Fresh Water

An adequate fresh-water supply is required for process water, for making of steam, for potable water and possibly for some cooling systems. It is assumed that there will be closed-circuit recirculating systems for both the making of steam and fresh-water cooling. Fresh-water requirements will be kept to a minimum for both purposes, being limited to make up for losses from leaks, evaporation and contamination. Depending on facilities installed, the size of the potable demand, and the processes selected, we estimate an initial fresh-water demand of from 8 to 10 million gallons per day minimum and possibly as high as 15 million gallons per day.

3.6.2 Salt Water

If the site is close to an adequate supply of sea water for cooling purposes and if the disposal of the heated water could be accomplished without detrimental environmental effect, the fresh-water requirements could be kept to the lower levels. In this case, we would expect salt-water demand for cooling purposes of some 40 to 50 million gallons per day.

3.6.3 Waste Treatment and Anti-Pollution

.The site must be suitable for installing safe and satisfactory means of disposal of both industrial and human wastes. The wastes will be both organic and inorganic and also might be in either liquid or solid form. Special waste treatment plants to process all industrial and human wastes connected with the industrial facility have been assumed. The plants would include necessary components, such as oil separators, aeration lagoons and filters designed to comply with all environmental regulations.

3.6.4 Electric Power

There must be either a source of electric power or the ability to provide for it. The quantity of power will depend very much on the industrial process considered. We are assuming an initial power requirement of 200,000 kw. This could be considerably increased depending on the metallurgical plants that might be attracted.

Should the additional power requirements represented by the new facilities not be met by the existing electrical grid and generating capabilities, new plants would be necessary.

In the case of Isla Mona, and possibly some other sites, a new special thermoelectric power plant would be constructed. This should be located near the new refineries to burn residual fuel produced locally and could be constructed at the same time. Any new plant is assumed to be tied into the Puerto Rican power grid, including that on Mona, by installation of a submarine cable link to the main island. See Appendix H.

3.6.5 Fuel

The refineries are self-sustaining insofar as their own fuel requirements are concerned and they will provide additional fuel to supply power plants, steam boilers and other industrial users of residual fuel. This fuel can be transported by pipeline or barge, but requires special provisions to keep the product heated above a relatively high pour temperature. Other large fuel users can be expected to locate near the petroleum industrial site and port. Some of the fuel can also be sold as bunkers for ships.

3.6.6 Access

The site must have existing or potential good access from both sea and land. There must be access to bring in raw materials to be produced and to take the products out. There also must be access for workers and for construction materials and equipment starting with the first phases of development. There must be a good connection with the port facilities and, ideally, the industrial site would be located adjacent to the port.

3.6.7 Labor

Any industrial facilities need an adequate supply of labor. This is presumed to be no particular problem in Puerto Rico where there is a large reservoir of unemployed labor that could be used, although training may be necessary in some cases. Depending on the size and type of industrial facilities, it is estimated that the operating labor force will be between 2,000 and 8,000 direct workers and many indirect within the plant area. During construction, as many as 8,500 workers can be expected.

3.6.8 Housing

Adequate housing for the plant labor within a reasonable distance of the industrial complex, along with transportation facilities from the housing area to the industrial plant, will be required. Sites that are close to existing masses of habitation for workers can probably absorb the influx and provide the requirements relatively easily. Other sites in less developed areas may need special provisions to help provide new housing. In the particular case of Isla Mona, it is assumed that complete new housing and amenities will be required.

The northeast section of Isla Mona could be developed into a model residential community. This high area overlooking the ocean is on the windward side of the island so it would be unaffected by the smoke of the refineries on the opposite coast. This community could be built during construction of the major facilities. Temporary housing and transportation for workers would have to be provided during the first one to two years of Mona development.

3.6.9 Schools, Shops and Social Services

In the case of Mona, the new community could become a model and a showcase for high-quality living in an industrial development. Complete service, cultural, educational and recreational facilities would be required.

The community should be planned carefully, with streets, utilities, parks, beaches and service facilities controlled by a special development agency. Individual homes, townhouses, apartments and business establishments could be built and sold or rented by private enterprise with standards for design and construction and added amenities established by the development agency.

At other locations, complete planning may be more difficult, if not impossible; nonetheless, planning for future development of government-supplied social services could influence development to a large degree.

3.6.10 Fire Protection and Safety

Special fire protection and safety provisions in addition to the normal community provisions are required for both the port and the industrial plant. For the port and tank farm areas, a special high-pressure, high-capacity salt-water system will be the central provision, with auxiliary equipment to give full capability in coping with oil fires.

4.0 SITE SELECTION

4.1 Criteria and General Considerations

4.1.1 Port Requirements

The port has been used as the key to locating potential sites. Critical factors for identifying a potential port site include the following.

4.1.1.1 Water Depth

It should be neither too shallow nor too deep. On the general chart, depths of 15 to 20 fathoms were used as a key indicator. Potential sites were examined for depths of 100 to 120 feet for VLCC berthing and maneuvering areas, about 60 feet for product tankers and heavier dry bulk materials, and 30 to 40 feet for other ships. Minor exceptions to these requirements and a few shoal spots did not rule out a site for first screening. Target maximum water depth considered for a structure or SPM was 200 feet, with up to 250 feet allowed as an exception for otherwise favorable sites.

4.1.1.2 Shelter

The port area should be provided reasonable protection against severe wave conditions, preferably by natural features and, if not, by mandate installations. While the VLCC ships are not particularly sensitive to ordinary sea conditions, they are susceptible to long ocean swells. Product tankers and other ships would be susceptible to the usual trade wind seas. Also, if the general sea conditions are too rough, there are problems for pilots and berthing masters while boarding the ships from small craft. Also, under such conditions, health officials in some ports have refused to board ships for clearance and have closed the port for long periods of time.

Rough sea conditions could impair the operation of the port, even though the larger ships could be safely berthed. In all cases, orientation of the ship and the berths to head the bow or stern into the most severe sea and swell conditions minimizes operational problems. It is possible, in some areas, to improve the shelter by construction of breakwaters. The feasibility of this depends on the water depth, the nature of the bottom and potential sources of high-density breakwater materials. It is believed that there are few sites around Puerto Rico where a breakwater-enclosed harbor for VLCC's would prove feasible.

4.1.1.3 Wind and Currents

The dominant factor concerning the wind is the trade wind with nearly constant direction from the east/northeast sector (see Figure 4). While these winds often reach rather high velocities, their constant direction makes location of the port in a relatively sheltered spot somewhat simpler than is the case in other areas, where wind direction is more variable. Currents for the most part are minimal and are not expected to affect ship operations appreciably. Aside from the effects of wind-induced sea conditions, the most important consequences of wind and current direction would be possible pollution from cargo spills, such as oil or certain bulk materials, as they would be greatly influenced by the winds and currents.

In selecting port sites, this factor must be borne in mind. Ideally, the port would be located where the prevailing winds and currents would blow any spilled cargo or other pollution away from valuable environmental and ecological areas.

4.1.1.4 Offshore Area

There must be sufficient area offshore reasonably sheltered at proper depths to locate berths, provide maneuvering areas and with safe approaches and departure lanes. Detailed requirements for these areas are given elsewhere in the report. To assist in identification of a site, we have assumed minimum ship turning circles with diameters of 3,000 feet minimum, 6,000 feet adequate, and 12,000 feet very generous. The ability to inscribe such circles in a sheltered area of suitable depth, with adequate approaches, is one test of a potential port site.

4.1.1.5 Upland

Onshore area, located as close to the berths as possible, should be provided to receive discharged cargo and to stockpile cargo to be loaded for export. The required areas are discussed elsewhere in the report for both petroleum tank farms and dry bulk cargo storage piles. In both cases, for petroleum liquids and for dry bulk cargo, this receiving and stockpile area should be located as close to the berths as possible. There have been examples of such areas being located as far as 30 miles from the berthing area in the case of petroleum. This, however, requires high-capacity booster pumps and increases electric power requirements markedly. In our opinion, it is not practical for the dry bulk cargo stockpile to be that far away from the berths. The storage area need not be absolutely level, but it must be reasonably so. Rugged hills are not suitable.

4.1.1.6 Shorefront

There must be sufficient shore frontage to provide access between the berths and the land areas and also to provide for construction of a sheltered harbor for service craft and, in some cases, supply vessels.

4.1.1.7 No Dredging

While it is possible to deepen natural water depths to provide sufficient depth for the deep-water port, large-scale dredging has been generally avoided. The difficulties of obtaining dredging permits for a large-scale operation with today's regulations could critically delay the port program. Further, there are ecological problems that are associated with dredging that make it undesirable in many locations. There would be particular concern about dredging operations in mangrove areas, in areas near fresh-water aquifers, in shellfish areas, in areas of living coral, in areas with unstable bottoms, and in areas with very fine-grained bottom soils. Minor dredging to improve otherwise naturally suitable areas is a necessity at most locations, and has been considered as reasonable. Otherwise, with the sole exception of the Caño to Tiburones site at Arecibo, any site that requires large-scale dredging has been assumed to be unsuitable.

4.1.2 Industrial Requirements

The main industrial requirement is adequate land of suitable terrain.

4.1.2.1 Area

Requirements are given elsewhere in this report. For first identification, areas of 1,500, 3,000 and 5,000 acres were looked for.

4.1.2.2 Terrain

Ideally, the industrial site will be level, relatively high ground, well drained, free of vegetation, free of human habitation, and with soils and geology that provide good foundation conditions. The ideal site is seldom found. Some ruggedness of the topography is acceptable if the soils are suitable. Suitability of the soil in such a case means stable soils that can be handled with common earth-moving equipment, without drilling or blasting. It is also possible to clear heavy vegetation, and it is possible to improve the foundation suitability of some soils, but this all adds to cost and must be balanced against alternate sites that may be free of such impediments. The most serious impediment is the presence of a large number of human inhabitants. The cost and delay for removal of habitations would constitute a serious impediment to any site. In addition, the social upheaval that would occur could act against the overall feasibility of the entire project.

4.1.2.3 Access

The site must have existing or potential access from both sea and land. Obviously, there must be access to bring in raw materials to be produced and access to take the products out. There also must be access for workers and for construction materials and equipment in the early phases. There must be a good connection with the port facilities and, ideally, the industrial site will be located adjacent to the port.

4.1.3 Services and Utilities

Details of the requirements for services and utilities are given elsewhere in the report. For site identification, a checklist of utility requirements that must be considered and, if they do not exist, must be potentially available, includes:

Electric power

Fresh water --Potable

--Boiler feed

--Process

--Cooling

--Wash

Sea water--Cooling

--Wash

Waste disposal--Liquid

--Solid

Fuel

It is probable that at all the sites considered, most of the existing utilities listed above are inadequate for a major new industrial facility of the size contemplated. It can be assumed that new utility facilities will be required, and the absence of any at present is not sufficient reason for site elimination.

4.1.4 Demography and Social Factors

Because industrial facilities require an adequate supply of labor, locating a site close to a large pool of skilled labor is an advantage. If there happens to be a high unemployment rate in the labor pool, the site has a further advantage from the social aspect. It is assumed that areas with high tax exemption allowances either have high unemployment rates or are relatively lightly populated and there are social benefits to locating a plant in these zones. In addition to labor supply and unemployment conditions, location of the plant should fit in with the Commonwealth's master development plan and should cause a minimum amount of disturbance to existing housing, recreational areas, transportation facilities and other social amenities. The port and industrial facilities by their nature will attract people, satellite plants, and service industries to the area. Therefore, location in an area where such development can be beneficially controlled is an advantage.

4.1.5 Environment and Ecology

Although it is a truism that the port and industrial facility should cause the least possible damage to existing ecosystems, this is sometimes a difficult point to evaluate as there are often wide differences of opinion so to what changes in ecology constitute damage. For instance, as an extreme case, the elimination of pollution in a body of water might restore a high degree of dissolved oxygen which would destroy the anaerobic ecosystems. Nonetheless, we believe that, along with common sense, a few comparatively simple rules can be established as preliminary criteria for identifying and screening potential port and industrial sites, with more detailed study to follow. Because it is obviously impractical to consider all coastal and land mass areas for detailed environmental study before a screening, the few best sites or a combination of sites will be chosen for intensive study. Final selection can then follow, based on detailed and thorough analysis of data. For our selection and preliminary screening of sites, we have established the following criteria.

4.1.5.1 Human Impact

We believe the first consideration for densely populated Puerto Rico should be a location that has the least adverse impact on the smallest number of people. This means the facilities should not be located in densely populated areas or in places where unavoidable air or water pollution or changed drainage patterns would affect large population centers.

4.1.5.2 Dredging

As previously described, large-scale dredging operations are usually detrimental to the environment and are to be avoided wherever possible.

4.1.5.3 Wind and Air

The site should be located so as to cause the least amount of degradation of air quality. This would place it if possible on the leeward side of land masses and population centers and in such a location and arrangement that there will be maximum dispersion of emissions. To meet this criterion fully, the site would be somewhere on the western end of Puerto Rico.

4.1.5.4 Oceanography

The site should be located so that the prevailing winds, current, and littoral wave pattern would disperse and dilute waterborne pollution, particularly oil carried on the surface. Ideally, the site should be located so that any pollution or spills would be carried away from the land mass and any underwater pollution dispersed in the open sea. The location should also be such that surface pollution could be caught, gathered and disposed of without endangering shore areas. Another factor is a location where disposal of cooling water and resultant thermal effects could be either turned into an asset or dispersed without detrimental environmental effects. Points of land jutting into the open sea with a strong current pattern of deep cold water would be ideal.

4.1.5.5 Mangroves

The development is to be located so as to avoid damage to major mangrove or estuarine areas. The presence of large undisturbed mangrove areas is a drawback to a port or industrial site.

Also, the existence of such areas down wind or down current from a proposed site is a drawback. If it is impossible to avoid mangrove areas, the site must be suitable for development with minimal direct or indirect effects.

4.1.5.6 Marine Ecology

The proven presence or even the probability of the presence of ecosystems with large numbers of finfish (especially those used for food purposes), mollusks, crustaceans, coral, sponges, or underwater vegetation is considered a drawback. While there is a lack of reliable data as to the degree of existence of marine and plant life in many locations, extrapolation based on known conditions can be used to assist in screening potential sites for this criterion. However, in view of the uncertain and incomplete data available, potential sites that are only suspected of having such biota but are otherwise highly suitable were not screened out on this basis.

4.1.5.7 Terrestrial Ecology

The existence of a true forest would be a drawback. Forests, bird nesting sites, natural wildlife, rare or endangered species must all be taken into consideration. A complete destruction of a system of wildlife would be considered a serious disadvantage. The possibility of safeguarding an ecosystem that might otherwise be endangered would be considered beneficial and a site advantage, even if the ecosystem is altered somewhat. Included in these considerations would be alterations to natural food and shelter, changes in fresh-water systems, and the effects of industrial activity, during both construction and operation.

4.1.5.8 Fresh Water

A site that potentially endangers a large potable water supply would be eliminated. No development or site that would adversely affect a large fresh ground water supply would be acceptable.

4.1.5.9 Antiquities

Although not in the environmental or ecological categories, any valuable antiquities or sites of historical interest are to be preserved, the same as any ecological treasure. The need to modify, move or demolish such treasures would be a drawback to a site. If development could be carried on with protection and continued exhibition of a point of historical interest, a port or industrial site would not be excluded for this reason.

4.1.5.10 Special Recreational Areas

Certain areas in Puerto Rico have unusual potential for desirable recreational development. This includes a good part of the southwest corner of the island, especially certain beaches in this and other areas. Where these areas have been identified, no industry or port sites have been considered.

4.1.6 Cost and Economics

A full analysis of comparative costs and economic factors is given later in the report. For site selection and initial screening, a rough evaluation of the comparative costs of different sites was made by comparing such key factors as dredging, terrain and topography of the upland areas, distance between port and industrial facilities, availability of labor, existence of housing and amenities, probable amount of site preparation for construction and the comparative cost of distribution within Puerto Rico. While this first evaluation was very broad, it was useful and tended to eliminate many sites that had other serious drawbacks. In particular, it eliminated sites in areas which are densely populated, have much cultural and structural development, are extremely rocky, have very poor and marshy soils that could not readily be improved, and require extensive dredging. With one exception, it eliminated offshore islands.

In the final screening, cost and economic impact is given a rating of prime importance. A non-feasible or uneconomic rating would eliminate a potential site no matter how attractive other features might be. To succeed, the project must be economically viable; only those cases that are so are worth further comparison.

4.2 Description and Identification of Potential Sites

4.2.1 General

A number of potential sites were investigated, with primary emphasis on their suitability for the petroleum facilities. Those found suitable were reviewed to determine their possibilities for handling other waterborne commerce, and for siting future industrial plants which could use the raw materials that might be brought in and could produce and export products that could be priced to compete with those from other sources.

The locations of the potential sites are shown on Figure 8. Some of the conditions existing in Puerto Rico, other pertinent information, and additional criteria which were taken into consideration in the appraisal of all the potential sites are given in the subsections which follow.

4.2.1.1 Winds

Puerto Rico is situated within the northeast trade winds belt. The winds are generally northeasterly in the autumn and winter and easterly in the spring and summer. Their strength averages Beaufort 3 to 4 (8 to 18 mph). The trade winds in the vicinity of the coast are modified by land and sea breezes. This effect may counteract or reinforce the trade winds. On the southern and western coasts, the sea breeze which occurs during the day would tend to counteract the trade winds, whereas the land breeze which occurs at night would tend to reinforce the trade winds. In any event, the winds on these two coasts are weak and would rarely interfere with berthing or deberthing of tankers. The winds are of most importance for dispersion of stack emissions from industrial and power plants.

Tropical storms and hurricanes occur fairly frequently in the Caribbean during the hurricane seasons, but Puerto Rico itself has experienced relatively few. Due to the limited size of Puerto Rico, there is practically no difference in frequency of tropical storm occurrence among the various port locations considered. During a hurricane's approach, at any of the locations studied all ships would have to leave their berths some time before the wind became strong enough to prevent departure.

4.2.1.2 Sea and Swell

Average sea and swell conditions are represented on Figure 4. From these data, it is evident that the western coast of Puerto Rico is well protected from sea and swell; thus there appears to be no reason to seek protected locations for facilities on the west coast. On the south coast, a not insignificant amount of sea and swell arrives from the southeast. In connection with a tropical storm or hurricane, high seas and swells may be observed from any direction, even if the hurricane causes only light winds on Puerto Rico. Swells from a distant hurricane may arrive without warning and set up a seiching action on the narrow, shallow coastal shelves of Puerto Rico. This phenomenon is known locally as "mar desbordada." Should such a situation catch a ship at berth, it would probably lead to extensive damage to both the ship and the berth. With prudent management of the terminal and modern monitoring of tropical storms, it should not be difficult to avoid this situation.

Sea and swell depend to a large degree on local bathymetry as the waves are modified by obstructions and by shoaling. Partial protection can be achieved by locating the facilities behind reefs or shallow water areas even though the depth of water does not approach zero in some of these areas. As previously mentioned, the west coast is well protected in itself; therefore, consideration for protection against sea and swell need not be taken there. The phenomenon of "mar desbordada" also depends on local bathymetry.

4.2.1.3 Currents

The surface currents around Puerto Rico are variable and weak but predominantly from east to west. Currents in Mona Passage are from south to north. Tidal currents are practically nonexistent.

4.2.1.4 Tides

The tides are so small as to be of no practical consequence. The spring tidal range is about one foot.

4.2.1.5 Rainfall

Rainfall is influenced by the topography and varies greatly throughout the island. Generally, there is abundant rainfall in the northern and eastern coastal regions with dry conditions in the west and south. Some locations in the southwest region approach desert conditions in dryness. Offshore islands vary, with their rainfall following an ocean pattern.

4.2.1.6 Topography

Most of Puerto Rico can be described as mountainous with coastal plains of various widths. The mountain ranges lie in an approximate east-west direction, with the major "Cordillera Central" dividing the western half of the country. Even so, it has passes through which highways have been constructed at intervals averaging only a few miles. Some peaks rise to over 1,000 meters in height. In some west coast areas the coastal plain disappears and steep hills rise directly from the sea. This is true of some of the coast in the vicinity of Aguadilla and of Rincon. In some coastal areas, there is low-lying swampy ground or level ground subject to flooding following the heavy rains, extending in places for several miles back from the cemented dunes or other coastal embankments. In other places there are beaches. Mona Island, one of the potential sites studied, is essentially a plateau, with rather steep cliffs on all sides and only one rather small low-lying level area near the western end of the south shore.

4.2.1.7 Geology*

Puerto Rico is the easternmost island of the Great Antilles. It was formed by the emerged crest of an elongated ridge trending east-west through Hispaniola, Puerto Rico and the Virgin Islands. The central structure is a Cretaceous to early Tertiary volcanic framework, flanked by thick mid-Tertiary to Quaternary sediments on the south and north shores and bounded by three deep and seismically active troughs: the Puerto Rico Trench on the north, the Anegada Trough on the east, and the Mona Passage on the west. The Puerto Rico-Virgin Islands platform is considered to have been internally stable since the late Eocene.

A 1959 study made on coastal features by Clifford A. Kaye recognized five types of shorelines in six separate stretches along the coast of Puerto Rico. These different shorelines exist mainly due to the following conditions: the presence of a central ridge, ruptured by long strike slip faults, extending from the west to the east coasts and flanked on the north and south by shallow water sediments; the different climatic regimes between the north and the south shores; the transformations with the time of the original features by broad climatic changes; and the past tectonic activity of the area.

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* This section is excerpted from Report WRA - E.S. - 15 of the Puerto Rico Water Resources Authority.

Seven rock sequences are exposed in Puerto Rico. These sequences are separated by unconformities and large transcurrent fault zones. The oldest sequence, late Jurassic to early Cretaceous Bermeja Complex on the southwest corner of the island, is composed of a classic Ophiolite-type suite of oceanic and mantle rocks. The sequences 2 through 5, Albian to Eocene in age, forming the central core of the island, are composed of a pile of volcanic rocks and some limestones. These sequences are intruded by graniodiorite plutons. The last two remaining sequences, Oligocene to Recent, are chiefly composed of limestones and surficial deposits, and form the coastal areas.

The carbonate formations present on the north and south coasts of Puerto Rico trend east-west and dip toward the sea. On the north coast, seismic profiles indicate that these formations extend 20 miles offshore with a constant dip and thickness (5,000 feet thick, 6 degrees to the north). The different formations, San Sebastian, Lares, Cibao, Aguada and Aymamon, rest conformably on each other. Only the youngest formation, the Camuy Limestone, rests disconformably on the Aymamon Limestone. A spectacular Karst topography is developed on the limestone terrain.

On the south flank of the Central Mountain Range, the cover of carbonates is of lesser aerial extension than the one on the north, and dips to the south. Two formations, the Juana Diaz Formation and the Ponce Limestone unconformable with the precedent, are well exposed west and north of the city of Ponce. East of Ponce, the carbonates are buried under thick alluvial fans forming a broad alluvial plain. Almost everywhere, a thick cover of secondary calcium formations. A submerged platform, 55 km. long and 15 to 18 km. wide, with water depths generally less than 30 meters, borders the south coast between Ponce and Punta Higuera. This platform is capped by more than 2,000 feet of carbonates (Ponce and Juana Diaz formations).

Overlying unconformably the Miocene Limestone, surficial deposits, Pleistocene to Recent in age, are composed of alluvial and coastal deposits. Along the north coast, the alluvial deposits form a probably reworked blanket of sand or sandy clay inside the well-developed Karst or occupy the valleys of Rio Arecibo, Manati, Cibuco-Indio and La Plata. Coastal deposits including cemented sand dunes (eolianite), sand dunes, lagoons, swamps, beach sand and beach rocks are distributed along the coast from Arecibo to Rio Grande. Offshore, Quaternary sediments are absent above the dipping limestone.

On the south coast, the alluvial deposits are distributed along the present rivers running south-south-east (Rio Seco, Nigua, Coamo, Descalabrado, Tallahoa, Yauco, etc.) or form a series of overlapping alluvial fans composing a broad alluvial plain. The alluvial plain rests unconformably on the mid-Tertiary carbonates, late Tertiary carbonates (Pliocene or Upper Miocene), or on the Cretaceous-early Tertiary Complex. Locally, at the toe of Cretaceous hills, Colluvium blankets the alluvial deposits. Coastal deposits of beach sand and gravels, swamps and coral reefs fringe the coast.

On the west and east coasts of Puerto Rico, the surficial deposits, mainly alluvium, fill the east-west valleys, probably the locations of transcurrent faults across the island.

4.2.1.8 Demography and Social Characteristics

The 1970 census records a resident population of over 2.7 million. Except for some of the higher inland mountain peaks, most of the island is developed and inhabited. The density of population varies from region to region, with the greatest concentration in the north around San Juan. Other major population centers are at Ponce on the south coast and Mayaguez on the west. The offshore islands off the east coast are also densely populated except for land held by the U.S. Navy. The offshore islands off the south and west coasts are almost completely uninhabited.

Of the total resident population, a little over 900,000 are estimated to be in the labor force, of which about 700,000 are males. Free migration between Puerto Rico and the continental United States tends to distort both population and employment figures. It is estimated that about 1.2 million Puerto Ricans live in the continental United States. However, there is considerable in- and out-migration between the island and the continent, so this figure is subject to continual change.

The total unemployment rate is reported to be 12% for the island as a whole, but with a higher rate in the west and considerable variation regionally. Generally, highest unemployment exists in the western regions, in particular in the southwest.

The economy is changing from an agricultural base (mostly sugar) to industrial. A little over 145,000 are employed in manufacturing. The number of manufacturing jobs is increasing by about 6,900 per year as compared to an increase in labor force of 20,000.

Most manufacturing is in small industries oriented toward abundant labor. Average labor rates in Puerto Rico have increased to the point where labor costs now compare with those in some states and are much higher than those in other countries in the Caribbean area. Labor-intensive industries, especially those directed toward unskilled labor, find Puerto Rico less attractive than formerly and some manufacturing plants have been closed and the owners of others are considering moving elsewhere.

On the other hand, tax incentives, other regulations oriented toward the U.S. mainland market, the large pool of trainable labor and the availability of land being taken out of agricultural use are attractive to some kinds of technologically oriented industries.

4.2.2 North Coast

4.2.2.1 Description of North Coast

The north coast of Puerto Rico from Punta Borinquen on the edge of Mona Passage extends in an almost easterly direction to the city of San Juan and then in an east-by-south direction to Cabezas de San Juan Point. From Punta Borinquen to Arecibo, there are numerous rocky cliffs with sand beaches and dunes between them. The prominent features are the high hills in the interior and high cliffs along the coast. The hills that terminate a mile west of Arecibo are mostly smooth grassy slopes backed by conical wooded hills up to 800 feet high.

Between Arecibo and San Juan, the coast is indented by several coves and bights, although none of them affords sheltered anchorage. The first 17 miles to Punta Puerto Nuevo consist of sandy beaches and dunes with occasional rocky bluffs; then there are numerous hummocks and rocky bluffs with short beaches between them in the 16-mile stretch to San Juan. A line of reefs enclosing numerous rocks lies about 0.5 mile offshore. A range of conical hills is westward of San Juan.

The coast from San Juan to Cabezas de San Juan trends in an east-by-south direction with a shore that is low and sandy except for occasional bluffs. The low land extends two to four miles inland and then the mountains rise to three large prominent peaks toward the eastern part of the island. The coast is indented by many coves with reefs and rocky islets lying 0.5 to a mile offshore; breakers show at many of the reefs.

With the exception of a potential artificially created site near Arecibo, there are no suitable sites for the deep-water port on the north coast. The prevailing northeast and easterly trade winds plus the exposure to occasional storms from the north result in sea and swell conditions that would be excessive even for VLCC ships at any exposed location along the north coast. It is doubtful that even single-point moorings would be suitable along this coast because of excessive outage time caused by heavy sea conditions. In addition, the area water which is deep enough for safe operation of the ships without being excessively deep for installation of a single-point mooring is too limited in extent. Finally, because of the great concentration of population existing along the north coast and the large investment in tourist facilities along this coast, we do not believe it would be advisable to locate a deep-water port for petroleum here. Any accidental spills or other pollution along this coast would adversely affect the people and economy of Puerto Rico. The existing wind, wave and current conditions could be expected to distribute an oil spill widely along the coast.

4.2.2.2 Potential North Coast Sites

The exception mentioned above is the possibility of a dredged harbor in the Caño Tiburones lowland area just east of Arecibo. It would be theoretically possible to dredge an enclosed basin at this location that would be suitable for port facilities. With a boom in place--except during ship movements--across the narrow inlet from the sea, an oil spill could be completely contained. However, the cost of the dredging and the possibility of further salt water intrusion in the surrounding land detract from this location as a port site.

The limestone cliffs which characterize much of the coast in the limestone terrain of Puerto Rico are replaced by Arecibo by broad low-lying coastal plains. Beach sand, cemented dunes and swamp deposits are prevalent in the vicinity. The major river of the area, the Rio Grande de Arecibo, has well developed alluvial deposits. On each side of the river the coast topography is well developed in the limestone. Further inshore, the topography is gentle.

4.2.3 East Coast and Islands

4.2.3.1 Description of East Coast

The east coast of Puerto Rico extends southward from Cabezas de San Juan to Punta Puerca and then southwestward to Punta Tuna. The coast is very irregular with projecting rocky bluffs separating the numerous small shallow coves and bays, and with hills within a mile of the shore. Reefs awash or bare at low water and shoals with less than 10 feet over them extend more than a mile offshore in places. A depth of 24 feet can be found through a partially buoyed channel from two to five miles off the east coast, so shallow draft vessels can avoid the much longer voyage required to pass outside the major eastern islands, but extreme caution is necessary to avoid the shoals near the route.

4.2.3.2 Potential East Coast Sites

The only good harbor area on the east coast, at the Roosevelt Roads Naval Reservation, is in full use by the U.S. government. The remainder of this coast has no suitable locations for a deep-water port. The shallow waters and reefs extending far offshore with the deeper water beyond exposed to the trade winds and subject to ocean swells, together with the fact that all oil spills would be driven ashore, rule out the possibility of a site to be studied on this stretch of coast.

4.2.3.3 Description of Eastern Islands

Several of the small islands lying to the east of Puerto Rico were reviewed as potential deep-water port locations. Brief descriptions of these follow:

a. Isla de Culebra--Located 16 miles east of Puerto Rico, this island is about 6 miles in length east and west. It is fairly high with a broken and ragged terrain. In the island's center, Monte Resaca rises to 650 feet; 1.5 miles to the east-southeast Cerro Balcon reaches 551 feet in altitude. The north shore is steep, with the 20-fathom depth contour lying about 1.5 miles offshore and nearly parallel to it.

The island is in a Naval Defensive Sea Area and Airspace Reservation. Navigation by vessels other than those authorized by the Secretary of the Navy is prohibited within the three-mile limit. These conditions eliminated it as a potential site.

b. Isla de Vieques--This largest of the Puerto Rican territorial islands is located about 6 miles off the nearest point of the east coast of Puerto Rico and forms the south side of Sonda de Vieques. It is 18 miles long east and west, and 3.5 miles wide near its middle. A range of hills extends the entire length of the island with a prominent hill at each end--Monte Pirata reaching 980 feet near its western end and Cerro Matias Jalobre which is 450 feet high and three miles from the eastern end. The island is wooded in places, especially its eastern half, including Monte Pirata. The geology of Vieques is similar to Puerto Rico's.

Naval restricted areas extend 1,500 yards offshore around the western part of the island.

c. Other Islands--Isla Culebrita, just over a half mile to the east of Isla de Culebra, is irregular in shape and about a mile in length. It is formed by three hills with low land between them and is covered with scrubby forest growth.

To the west of Culebra is Luispena Cay which rises to a peak in the center. The south and north ends are joined to the main part of this small island by low necks. Punta Cruz, forming the southwest point, has a prominent whitewashed cliff.

Neither of these two islands would be suitable as a port site.

4.2.3.4 Potential Eastern Island Sites

There is one possible location for a port near the western end of Vieques' south shore. Here the sea bottom slopes gradually to suitable depths for vessel berths. The bottom is in general rocky, with little sedimentation. The adjoining land area is a swampy marsh bounded by volcanic ranges on the north.

4.2.4 South Coast and Islands

4.2.4.1 Description of South Coast

The south coast of Puerto Rico extends in an almost due westerly direction for its full length from Punta Tuna to Cabo Rojo. It is very irregular, with projecting brush-covered points between shallow coves and bays; fringing reefs close to shore make landing difficult and often dangerous in most places. Except at the eastern and western ends of Puerto Rico, the land is generally low near the shore, with prominent high hills in the interior. Many reefs and islands are from two to five miles offshore, then the bottom increases rapidly to great depths, making soundings of little use to indicate danger or distance from shore. Small vessels steered by knowledgeable local sailors sometimes hug the coast inside the outer reefs to avoid heavy seas outside.

The western end of the coast, between Punta Vaquero and Cabo Rojo, has been designated a reserved area and is off-limits for industrial port developments.

4.2.4.2 Potential South Coast Sites

There are a number of possible sites on the south coast. Some of these have been previously identified and suggested by other investigators and have varying degrees of merit. In our opinion, the most likely include: offshore of Aguirre-Jobos Bay area, several sites near Ponce, adjacent offshore areas near Punta Cabullon and areas off Guayanilla. Guanica, Cabo Rojo and other potential sites in the southwest have not been considered since it was agreed the area would be off-limits to industrial development.

4.2.4.3 Description of Southern Island Sites

a. Isla Caja de Muertas--This island, located about midway of the 75-mile stretch of coast between Punta Tuna Light and Cabo Rojo, is about five miles offshore and prominent. Except for a 170-foot steep hill at the southwest end, the land is low-lying.

b. Other Islands--There are no other significant islands off the south Puerto Rico coast. Numerous small islands and reefs exist particularly off Ponce, Santa Isabel and Jobos, but all are too small for consideration as potential port sites.

4.2.4.4 Potential Southern Island Sites

The only offshore island on the south side of Puerto Rico that could possibly be considered as suitable is Isla Caja de Muertas. This island, approximately 500 acres in extent, is too small for a major development and also would be very difficult to acquire.

4.2.5 West Coast and Islands

4.2.5.1 Description of West Coast

The west coast of Puerto Rico extends generally northward from Cabo Rojo to Punta Higuero, then curving northeastward and north to Punta Borinquen. The coast is irregular, with projecting wooded points between shallow bays. Places for small boat landings can be found in ordinary weather, but landing is dangerous in rough weather. In the southernpart, the land is low near the shore, with prominent high hills in the interior. Between Cabo Rojo and Bahia de Mayaguez, reefs and shoals with depths of 30 feet or less extend up to 13 miles offshore; lighted buoys mark the extension of the shoal area. North of Bahia de Mayaguez, dangerous depths extend only one to two miles from the shore. Small local vessels are an 18-foot buoyed passage one to two miles offshore between Cabo Rojo and Bahia de Mayaguez.

The area from Cabo Rojo to Mayaguez has been designated a recreational area off-limits to industrial port development.

4.2.5.2 Potential West Coast Sites

North of Mayaguez there are possible sites in Anasco Bay, near Rincon on the west side of Punta Higuera, on the north side of Punta Higuera, and in the area of Aguadilla, both north and south of the town.

4.2.5.3 Description of Western Islands

a. Isla Mona--Prominent among the major islands, Isla Mona, located in the middle of the southern part of Mona Passage, is approximately six miles long east and west, and four miles wide. It is a Commonwealth forest preserve and, except for a few government employees, is uninhabited.

The island is composed of limestone and from the east appears perfectly flat on top, breaking off abruptly at the water in a vertical whitish cliff about 175 feet high. On the northwestern and northeastern coasts, there are extensive caves which run in every direction, but are so obstructed by stalactites and stalagmites in places that it is almost impossible to pass. These caves were used as hideouts by pirates for nearly three centuries. The western, southern and southeastern sides of the island are fringed with detached coral reefs through which there are openings at intervals suitable for small boat passage.

The 100-fathom curve lies about one mile offshore, except on the southeast side where it is about 1.7 miles offshore and on the southwest side where it is only about 0.3 mile offshore. With a strong wind from any direction, the sea draws around the island and generally into all the anchorages.

Isla Mona Light, 231 feet above the water, is located on Cabo Este, the eastern extremity of the island.

Vertical cliffs with deep water close to shore extend from Cabo Este northward and westward to Cabo Barrionuevo, the northwest cape of the island. Here a mass of rock shaped like two sawteeth on top projects from the base of the cliff. This feature can be observed from the north and the southwest.

The southernmost point of the island is surmounted by a large balanced rock. Punta Oeste, the westernmost point, is a low, narrow ridge covered with brush which projects nearly a mile westward from the cliffs; a reef extends 0.3 mile westward of the point.

b. Isla Monito--This is a 213-foot-high bare rock about 0.2 mile in diameter located approximately three miles north-northeast of Isla Mona.

c. Isla Desecheo--Located 27 miles to the northeast of Mona and 12 miles west of Punta Higuero, Isla Desecheo is a 715-foot-high wooded island about one mile in diameter. Visible for more than 30 miles in clear weather, the island is one of the best landmarks for Mona Passage and the west coast of Puerto Rico. It is a forest and native bird reserve and is uninhabited.

4.2.5.4 Potential Western Island Sites

The most suitable island on the west side is Mona which has relatively protected water of suitable depth on the southwest side. It is undeveloped land and possibly is a suitable site for an industrial development. The other offshore islands of Monito and Descheo are both small, have very steep sides without suitable landing places, and have insufficient water area nearby which is shallow enough for berthing structures.

4.2.6 Inland Industrial Areas

4.2.6.1 Existing Industrial Areas

a. Eastern Half--Centered in the Las Piedras and Yabucoa areas of Humacao District, industry is concentrated near the Humacao and Santiago Rivers. The latter is at the eastern end of a valley bounded on the south by the Cuchilla de Panduras headland. The area is described as a broad alluvial plain which may be bounded by faults.

b. South Central--The coastal area of Guayama District is the site of substantial industrial development. The coast in this part of Puerto Rico consists of a piedmont alluvial plain bounded on the north by gentle slopes which run to the foot of a steep mountain front. The industrial area is on these flat to gently sloping sedimentary deposits. The northern boundary is the Sierra de Cayey.

c. Southwest--Most of Puerto Rico's major heavy industry is located in the vicinity of Guayanilla and Penuelas. The large Commonwealth Oil Refinery and associated petrochemical plants are in this area, as is the large new south coast power plant.

d. West Central--Except for several distilleries and a few other industries in and near Mayaguez, there is no large industrial activity in the west central portion of Puerto Rico, the terrain being at the western end of the Cordillera Central and hence very rugged.

e. Northwest--Except for the Ramey Air Force Base which has essentially been deactivated, the northwest portion of Puerto Rico is undeveloped. Further to the east, in the vicinity of Arecibo, there is a large plant manufacturing phthalic anhydride, and other smaller industries.

f. North Central and Northeast--There is considerable industrial development in several inland areas which lie southwest, south and southeast of San Juan. Due to the high population density, it would not be possible to undertake extensive further industrial development.

4.2.6.2 Potential New Inland Sites

It was requested that consideration be given to the possibility of locating the petroleum industrial center at an inland site, relatively unpopulated and that would cause a minimum of social disturbance. In particular, the less populated areas of the western part of the island were to be considered. We concentrated our search in the inland areas of Aguadilla, Moca, Isabella and San Sebastian. All of these regions are extremely rugged and hilly and would increase construction costs greatly. Further, because of the meteorological conditions, areas south of the steep mountains of Moca and San Sebastian could be expected to increase air pollution to an undesirable degree. Sites identified have been the inland areas of Aguadilla near the Ramey Air Force Base installations, the northern part of the township of Moca and areas near the town of Bayaney. Most of this land is agricultural with the exception of Ramey ammunition dump. The area around Bayaney and, to a lesser degree, the northern part of the Ramey ammunition dump is a watershed area for potable water supply reservoirs. There appear to be no other special environmental or ecological features or historical sites near these locations that require special protection.

4.3 Preliminary Screening

4.3.1 Objectives

The preliminary screening was to rule out those sites that obviously would be neither economically attractive nor socially acceptable. The objective was to identify the five or six most favorable sites for more detailed analysis and comparison. Actually, seven sites selected for further study. The figure numbers enclosed in the rectangles refer to the tentative development plan figure numbers for the various cases entering into the further study for the respective site.

4.3.2 Methodology

The method for preliminary screening was, first, general data gathering, then comparison, then rough rating, and finally selection. The first step in data gathering was to examine the physical characteristics of the identified sites as revealed by large-scale topographic maps and navigational charts and then to examine them by air and personal reconnaissance to verify the general accuracy of the maps. In the case of Isla Mona and the northwest sites, physical check surveys of charted water depths and of sub-bottom conditions were also made. In addition, a geophysical check survey was made at Mona.

After the reconnaissance surveys, further available data in the form of reports, studies and government publications were gathered and examined and the principal features of the sites identified. These were then discussed with experts of appropriate government agencies and other knowledgeable consultants and the site conditions further described.

The screening process itself started with the comparisons. The sites were compared on the basis, first, of general physical characteristics: did they "look right"? No sites were ruled out solely on this basis, but rather it was used as reinforcement for other factors. The next comparison was on the basis of apparent cost differentials and economic factors. A site that was obviously too costly to be economical would be ruled out forthwith. No matter what other favorable circumstances might exist, the project and hence a site must be economically viable and attractive.

Finally, the sites were compared for obvious differences in social impact, environmental and ecological factors, flexibility of use and future potential.

Both port development and industrial development were considered at a site. In some cases, it was obvious that combinations of ports and different industrial sites might prove attractive. These combinations were identified, but not compared as a separate case for preliminary screening.

The screening was primarily on the basis of proposed petroleum operations with other port and industrial potential as an added factor.

4.3.3 Screening

4.3.3.1 Vieques

Most of Vieques is owned by the U.S. Navy. The port site is on the south side of Vieques adjoining the only belt of non-Navy owned property on Vieques Island. There is somewhat limited space for deep-water berths and we would expect exposure to sea conditions from the east and southeast that would often restrict port operations. The effect of oil spills would be felt on much of the east coast and probably also the eastern south coast of the main island of Puerto Rico. The only practical general or service harbor would have to be in one of the two phosphorescent bays. The only industrial site that could be practically considered would be an area bounded on the south by the shoreline adjoining the port site. Space is limited and industrial use would destroy some recreational potential. There is a large unemployment condition, but the labor force is largely untrained for industrial purposes. At least initially, a large influx of outside labor could be expected, putting a severe strain on housing and amenities. Social problems and resentment from the present local population might occur. Because of its island location, transportation costs to the main island would be relatively high, making this location only feasible for a large development which could not be supported under present conditions. This site was screened out.

4.3.3.2 Aguirre-Jobos

There are generally good conditions for berting medium-draft ships off Jobos Bay, but deep-draft berths would be almost eight miles offshore.

The best petroleum product port and bulk dry cargo sites would be near the channel entrance to Guayama Harbor, which was dredged in the Laguna de las Mareas. There is ample onshore undeveloped land area for port upland and industrial facilities. Much of this land is government owned and zoned for industry. This site is relatively remote from other industrial areas and is subject to the general concern of those living near the south coast regarding the effects of an oil spill. In addition, immediately to the west of Jobos Bay is located what is reported to be the largest unspoiled estuarine and mangrove area in Puerto Rico. There also may be a problem with wind conditions and potential air pollution from industrial operations. For these combined reasons, this site was dropped in initial screening, but was reinstated for further study at the request of PRICDO because of the large amount of government-owned land available. It is possible that this might be a good secondary industrial port site.

4.3.3.3 Ponce East (Punta Cabullon) and Ponce West

a. Ponce East (Punta Cabullon)--With the deep-water berthing area to the northwest of Isla Caja de Muertos, this site is one of the best in Puerto Rico from a marine or port standpoint. There is also ample undeveloped onshore land. The main disadvantage is its close location to the city of Ponce and the potential for further air pollution. Its other advantages are so great, however, that it was kept in contention for further study.

b. Ponce West--This site is limited in its satisfactory deep-water area and has practically no adjacent onshore land area available. It is also close to a major recreational beach for Ponce. It offers no particular advantage over other sites nearby. This site was screened out from further consideration.

4.3.3.4 Guayanilla

This site with berthing areas offshore south of Punta Verraco and with a large amount of land close to the marine installations presents a good deep-water port possibility. It is also close to the largest single existing oil refinery and to the majority of petrochemical plants presently existing in Puerto Rico. Because of the presence of industry now, it is believed that little further damage could be done to the local environment and immediate ecology. It shares the common drawback of south coast sites due to possible damage to the recreational southwest coast from oil spills. Nonetheless, it was kept in consideration for further evaluation.

4.3.3.5 Añasco

From a marine standpoint, berthing facilities in the Bahia de Añasco would be the best on the west coast and possibly the entire island. This presents one of the best potential port sites in Puerto Rico. There are social and environmental disadvantages, but this site was given further study because of its port potential.

4.3.3.6 Rincon South

Berthing areas close to shore in deep water are possible immediately south of the town of Rincon. There are restrictions in that there are offshore reefs that present a potential hazard to the maneuvering of large ships. There is also the drawback of limited adjacent land area. It would be possible to develop this site as a major deep-water port in conjunction with an Añasco site for the smaller vessels. This site has been given further consideration.

4.3.3.7 Rincon North Side

This area near Punta Higuera is subject to considerable wave action throughout most of the year; indeed, it is one of the best surfing beaches in Puerto Rico. To develop it as a major port would require a major breakwater, probably costing well over $100 million, which would be an additional cost compared to other sites. For this reason and because of its recreational potential, this site was screened out from further study.

4.3.3.8 Aguadilla

Aguadilla presents a possible deep-water port berthing area for large ships close to shore. Its main drawbacks are disturbed sea conditions during a considerable portion of the year, plus a limitation on available land area. Nonetheless, it has been studied further.

4.3.3.9 Arecibo

Development of a port in this area would require dredging of the Cano de Tiburones. To dredge this sufficiently (to a depth of approximately 100 feet) for a major deep-water port would require over 150 million cubic yards of dredging. We estimate this would cost at least $75 to $80 million even at optimum rates, if rock were not encountered. It is likely that rock would be encountered at the depths required and the costs would then be much higher. It is unlikely that a deep-water petroleum port at this site would be economically feasible. The site would normally be screened out, but since it might be feasible for a container-ship port or for lower-density dry cargoes and since the land is of little use in its present condition, the site was given further consideration.

4.3.3.10 Mona

Isla Mona presents some concern about sea conditions in the berthing areas as well as the condition of the base limestone rock. Preliminary analysis indicates the probability of the berths being operable most of the time with acceptable outage. It is also the largest non-mountainous, uninhabited land area in Puerto Rico. Although it would probably prove economically unattractive for small development, a large one would be possible. This site was therefore studied further.

4.3.3.11 Inland Sites

The inland industrial sites at Bayanez and the Ramey/Moca areas were suggested as alternates to avoid the environmental and social impact problems of coastal sites. Obviously, they are economically inferior to coastal industrial sites located next to ports. Inland sites require extra pipeline connections or other transportation provisions, and would present disposal problems for liquid wastes and problems for cooling water. Further, air pollution from inland industries would obviously be spread over a wider land mass area than would be the case with downwind coastal sites. Further, in Puerto Rico, an inland site would be more remote from the major petroleum market and consuming areas which are mostly coastal. This would present internal distribution problems and further increase costs. The only reason for considering an inland site would be the availability of suitable land that would be unoccupied and otherwise free of detrimental social impact. The two inland site possibilities identified do not exactly fit that description.

The site at Bayanez is lightly populated and the land does not seem to be intensely used for other purposes, but it does lie in a major potable water supply area. Further, the land is quite rugged and, combined with difficult access, would result in high construction costs. This site was screened out.

The site near the Ramey ammunition dump appeared to be a better possibility and was studied further.

The potential sites in central Moca are all too rugged and would result in excessive construction costs.

4.3.3.12 Summary of Preliminary Screening Results

These results are summarized in the following table:

Summary of Potential Deep-Water Ports With Industrial Site Combinations

Port	Industrial Site
o Vieques	o Vieques
* Jobos	* Jobos
* Punto Cabullon	* Punta Cabullon
	* Guayanilla
	* Jobos
	o Inland
	* Añasco
o Ponce West	Same
* Guayanilla	* Guayanilla
	o Inland
	o Añasco
* Añasco/Rincón	* Añasco
	o Rincón
	o Inland
	* Guayanilla
	o Culebrinas
o Rincón North Side	o Rincón
	o Culebrinas
	o Aguadilla
* Aguadilla	* Aguadilla
	* Inland
	o Culebrinas
* Arecibo	* Arecibo
	o Inland
* Mona	* Mona

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* Indicates site considered for further study.

o Indicates screened out in preliminary round for obvious economic or environmental reasons.

Note: See Figure 8 for locations.

5.0 SITE EVALUATION AND COMPARISON FOR PETROLEUM CASE A

5.1 Requirements and Specific Criteria

Case "A" assumes all new petroleum product requirements for Puerto Rico will be imported. It assumes the existing refineries will stay in operation at their present level, and will continue their present level and patter of product distribution. New facilities would be required to handle the imported products. These include tanker berths, oil transfer systems, tank farms, and new or expanded internal distribution systems.

There are two possibilities for providing these new product import facilities. One plan is to provide a number of small marine terminals near the principal centers of petroleum product consumption, which is designated as the "multi-terminal" case or sub-case. These terminals would have only one or two berths each, in existing harbor areas; the size of incoming tankers would be limited by the existing channel and harbor depths. The other plan is to develop a large central import terminal, with primary distribution systems to the centers of the principal consuming areas. This terminal would be capable of handling the largest product tankers that could be loaded at refineries in the Caribbean area, the United States, and other potential sources of petroleum products.

There is greater efficiency if terminal facilities are concentrated in one large site. Decentralizing the terminals requires some duplication of unloading facilities but this extra cost is reduced by savings in the distribution system costs. Berth and tank farm requirements for the central terminal sites to be studied were determined in 3.1.5.2, and corresponding distribution systems were determined as described in 3.1.5.3. Facilities for individual terminals of the multi-terminal cases have been apportioned by the assumed share of new product requirements to be handled. In this sub-case, more tanker berths were assumed than would be needed at a central terminal because of the smaller size tankers. Also, more terminal receiving tankage was assumed in all, compared to the central terminal case.

For both the multi-terminal and central terminal cases, it was assumed that the secondary distribution systems to the ultimate users, from the centers of the principal consuming areas, would be essentially the same.

5.2 Physical Comparison

Special drawings for port and terminal facilities have not been prepared for Case A. In the case of the central terminal sites which were investigated, the drawings prepared for Case C will serve as guides to the site descriptions below. (See Figures Nos. 24 through 35).

5.2.1 Multiple Import Terminals

In this case it is assumed that special petroleum import terminals would be provided at San Juan, Ponce and Mayaguez, for consumer products, and at the main petrochemical centers of Guayanilla and Guayama, for naphtha and other feed stocks. It is possible that these new facilities could be appended to those that presently exist, and operated by adding personnel to the existing terminal organizations. However, we have assumed that additional land, new berths, tanks, and other structures would be required. It is also possible that new product facilities would be required to deliver fuel oil directly to new thermal electric power plants. This would depend on the power plant location, market conditions and the ability of existing refineries to supply fuel oil requirements. For simplicity, we have assumed that special import facilities will not be required at the power plants and that existing secondary distribution systems will be continued and expanded as needed. Further, we have assumed that, if required, imported fuel oils would be blended with locally refined fuel oils at the point of import corresponding to one of the petrochemical centers.

5.2.2 Central Import Terminal at Arecibo

The petroleum product import facilities at Arecibo would be within the dredged basin, as shown on Figure 24, and obviously would not be economically attractive in itself. If it was combined with a port, developed for other purposes, the incremental cost might be low enough to make this an attractive site. The alternate to develop ocean berths in the open Atlantic would not be an attractive operation, in our opinion. It might be possible to develop a sea-berth-type facility for a single product to serve a power plant, but not the multiplicity of products that are contemplated for the central terminal.

5.2.3 Central Import Terminal at Jobos

there are two possibilities of developing a product import terminal at the Jobos site. One would be with offshore berths as indicated for the product export berths on Figure 26. The other would be to locate berths in the dredged harbor near the existing petrochemical plant pier and, in our opinion, would be more satisfactory. It is possible that at certain times of the year, the easterly trade winds cause strong seas from a southeasterly direction. Rough waters could cause considerable port closure times for the outside berths. The relatively small product tankers that could be expected to import products would be particularly susceptible to this. Tanks could be located in the petroleum tank farm area shown on the drawing.

5.2.4 Central Import Terminal at Punta Cabullon

We are assuming the central product import terminal facilities would be similar to those provided for product exports for Case C on Figure No. 28. Minimum facilities would include product berths and a portion of the petroleum tank farm indicated, plus a similar service harbor in the Caleta de Cabullon. It is probable that this minimal service harbor will require no dredging. Other non-petroleum activities shown on Figure 28, such as the bulk and dry cargo port facilities, could also be provided without encroaching on the petroleum berths. If dry bulk and container facilities are required, we would expect some form of breakwater protection will be necessary, although possibly not to the extent shown on Figure 28. In this event, it might be advantageous to place the petroleum berths within the protection of the breakwater harbor. Our preliminary analysis indicates that breakwater protection will not be necessary at the petroleum berths for most of the year, but that some reorientation of the berth may be required.

5.2.5 Central Import Terminal at Guayanilla

Possibly, the new berths could be adjacent to the existing petroleum pier of the Commonwealth Oil Refining Company in the Bahia de Guayanilla. This would require some dredging. It is also possible to locate berths off Punta Verraco, where the bulk berths are shown on Figure 30. Other types of port facilities could be developed as indicated on Figure 30.

5.2.6 Central Import Terminal at Añasco/Rincón

Petroleum product import berths could be located as shown for the product export berths in Añasco Bay on Figure 32. It is also possible to locate the product import berths at Rincón. Of the two locations, we believe the one in Añasco Bay would prove more satisfactory from an operating standpoint. It would be particularly recommended if developed in conjunction with other port facilities.

5.2.7 Central Import Terminal at Aguadilla

There are three alternate courses of development for a petroleum import terminal at Aguadilla. One would be substitution of product berths for the crude oil import berths indicated on Figure 34. The other two would be substitution of product import berths for those export berths, either outside or inside the breakwater is recommended. There is some question, in the case of Aguadilla, as to the down time from adverse sea conditions during the year. As noted previously, ocean swells from northeast trade winds and from occasional far off northerly storms, refract around Punta Borinquen and cause considerable disturbance in the Aguadilla area. There is a reasonable expectation that the berths shown will receive some protection from the land mass of the promontory of Punta Borinquen, but this can only be determined by further study and field measurements. Other port facilities could be developed behind the breakwater, as shown on Figure 34. It might be possible to provide some bulk cargo berths at the location shown for crude oil import berths. In this case, conveyors could be connected to the shore on overhead trestles, with stockpiles in the in-portions of the area designated for the petroleum tank farms.

5.2.8 Isla Mona

Because of its remote island location, Isla Mona would not be suitable just for a product import terminal.

5.3 Cost and Economic Impact Comparison

5.3.1 Cost Determination

Capital costs for Case A site evaluations were built up by the use of unit costs for piers, tanks, pipelines, and other features. The same unit costs were used to build up the capital costs for the other Cases of this study. Land values were based on the estimated areas needed and applying the cost per unit area obtained from the Planning Office for the site in question. In the case of the primary distribution systems, lowest costs were found to be those by pipeline for all "clean" or consumer products, with barge movement only for #6 and other residual fuels.

In past years, privately-owned, water-transport systems were able to move the "clean" products between marine terminals at a lower cost than privately-owned pipelines, even though the water route involved somewhat more mileage. Present costs of building and operating new oil carrying vessels for a profit have increased significantly that the unit cost per barrel between coastal points is almost the same as the cost via a new privately-built-and-operated pipeline. As mentioned in 3.1.5.3, cost comparisons of this study are based on the assumption that all pipelines would be financed and operated by the government, while all mobile transport facilities, such as barges and trucks would be owned and operated by private companies. Costs of hauling clean products by trucks, as an alternate to pipelines for the primary distribution system, would be uneconomical even if the pipelines were privately owned. No drawings were prepared for the distribution systems for the imported products of Case A. These assumed distribution systems, for each site studied, are the same for each corresponding site for Cases C and D. They are shown in the odd numbered figures in the Case C group, numbered 25 through 35, and the Case D group, numbered 39 through 47.

The Capital costs of all Case A installations and the installations for all other Cases were based on facilities capable of handling estimated throughputs for the year 1985. The 10-year revenue period, from 1976 through 1985, assumes a growth in accordance with the forecasts of new product needs. It is also assumed that present requirements will be distributed with existing systems. Pipeline power costs and total barge costs for the 10-year period were based on the estimated total volumes to be handled during the period.

All costs are estimated on the basis of 1973 dollars and 1973 construction cost levels.

5.3.2 Cost Comparisons

There are four tables at the end of this Chapter 5, entitled:

Site Comparison - Summary of Cost of Government Facilities
Total Capital Cost - All Government Facilities
Capital Cost of Petroleum Port and Terminal Facilities
10-year Operating Costs for Petroleum Facilities and Barge Hire Costs

Each of these contains the respective Case A cost data for the multi-terminal sub-case and for each site, so they may be readily compared.

The most significant comparison is in the first table, which contains a tabulation of total 10-year costs for each site, and hence the total revenue required for each.

The multi-terminal case would involve the lowest overall cost for terminalling and distribution.

The development of a central import terminal for the purposes assumed for Case A is more costly and would not appear attractive, economically, unless it permitted the use of larger, more economical tankers, or lower-cost sources of products. Cost, as tabulated, make it possible to compare the corresponding costs for other cases of this study.

The comparative attractiveness of Alternate A for meeting Puerto Rico's future petroleum product needs can be determined by comparing the total delivered cost to the consumer with the equivalent by other cases. The overall cost will include the landed cost of products, including purchase price, ocean transport and duty, as well as terminalling and distribution costs.

5.4 Demographic and Social Impact Comparison

There is no strong impact to be made for any of the alternate sites within Case A. The greatest impact is in comparison with the other cases since Case A would probably result in the greatest delivered cost of petroleum products to the Puerto Rican consumer and using industries. Further reliability of supply would be least secure.

5.5 Environmental and Ecological Factor Comparison

The multiple terminal case would expose the environment to more risk of pollution from operational spills, accidents and disasters than the other cases. Four to five product tankers per day would have to call as their average size would be relatively small because of existing port and channel depths. Some of these ships could be expected to call at more than one port in the multiple-terminal case. This further increases the probability of pollution as compared to alternates which require fewer, but larger, ships arriving at a single port.

5.6 Comparison of Flexibility

The multiple terminal alternate has no long-range flexibility, except to be converted to barge distribution terminals--if one of the other cases were implemented in the future. The central terminal developments could be developed into Case C or Case D facilities at most sites. There is only incidental flexibility for future non-petroleum use with the Case A facilities.

SITE COMPARISON
SUMMARY OF COST OF GOVERNMENT FACILITIES
CASE A--1985

(Dollars in Thousands)

Site	Capital Cost	Rank	10-Year Operating Cost	Rank	Total 10-Year Cost	Rank	Annual Average Cost	Rank
A. Multiple Terminals	$69,300		$ 67,740		$137,040		$13,704	
B. Central Terminal At:								
1. Aguadilla	63,780	4	111,910	4	175,690	4	17,569	4
2. Añasco/Rincón	63,550	3	111,800	3	175,350	3	17,535	3
3. Punta Cabullon	57,690	1	102,590	1	160,280	1	16,028	1
4. Guayanilla	58,230	2	106,510	2	164,740	2	16,470	2
5. Jobos	71,270	5	116,080	5	187,350	5	18,735	5
6. Mona	-	-	-	-	-	-	-	-
7. Arecibo	-	-	-	-	-	-	-	-

TOTAL CAPITAL COST - ALL GOVERNMENT FACILITIES
CASE "A"--1985

CENTRAL IMPORT TERMINAL SITES
(Dollars in Thousands)

	Multiple Terminal	Aguadilla	Añasco/Rincón	Punta Cabullon	Guayanilla	Jobos
1. Petroleum Terminal	$69,300	$46,580	$47,150	$47,090	$49,630	$55,270
2. Petroleum Industrial Site						
3. Support Facilities						
4. Distribution Pipeline		14,200	13,400	7,600	5,600	12,000
5. Distribution Barge Terminals		3,000	3,000	3,000	3,000	3,000
Total	$69,300	$63,780	$63,550	$57,690	$58,230	$70,270

CAPITAL COST OF PETROLEUM PORT AND TERMINAL FACILITIES
CASE "A"--1985

CENTRAL IMPORT TERMINAL SITES
(Dollars in Thousands)

	Multiple Terminal	Aguadilla	Añasco/Rincón	Punta Cabullon	Guayanilla	Jobos
1. Land acquisition						
a. Land	$ 1,800	$ 800	$ 1,000	$ 1,400	$ 1,000	$ 1,400
b. Houses						
2. Dredging and navigational aids		500	500	500	500	500
3. Berths						
a. Crude						
b. Product	24,000	12,000	12,000	12,000	12,000	12,000
4. Trestle lines to shore	2,500	1,200	1,500	1,050	3,660	8,160
5. Tank Farm and piping	32,000	20,000	20,000	20,000	20,000	20,000
6. Service craft		5,000	5,000	5,000	5,000	5,000
7. Service harbor and miscellaneous		1,000	1,000	1,000	1,000	1,000
Subtotal	$60,300	$40,500	$41,000	$40,950	$43,160	$48,060
8. Engineering and administration (15%)	9,000	6,080	6,150	6,140	6,470	7,210
Total	$69,300	$46,580	$47,150	$47,090	$49,630	$55,270

10-YEAR OPERATING COSTS FOR PETROLEUM FACILITIES AND BARGE HIRE COSTS
CASE "A"--1985

CENTRAL IMPORT TERMINAL SITES
(Dollars in Thousands)

	Multiple Terminals	Aguadilla	Añasco/Rincón	Punta Cabullon	Guayanilla	Jobos
1. Interest Cost						
a. Port and terminal	$23,090	$ 15,530	$ 15,720	$ 15,700	$ 16,540	$ 18,420
b. Industrial site						
c. Support facilities						
d. Distribution		5,730	5,470	3,530	2,870	5,000
Subtotal--Interest cost	$23,090	$ 21,260	$ 21,190	$ 19,230	$ 19,410	$ 23,420
2. Operating Cost						
a. Port and terminal						
. Labor	8,000	26,900	26,900	29,300	29,300	31,700
. Consumables	2,000	6,700	6,700	7,300	7,300	7,900
b. Support facilities						
. Labor						
. Consumables						
c. Distribution						
. Labor		4,250	4,600	3,110	2,240	3,810
. Consumables		9,910	9,470	7,270	5,240	8,890
. Barge Hire		16,160	16,160	10,720	16,480	10,720
Subtotal--Operating cost	$10,000	$ 63,920	$ 63,830	$ 57,700	$ 60,560	$ 62,700
3. Maintenance						
a. Port and terminal	34,650	23,290	23,500	23,540	24,820	26,640
b. Industrial site						
c. Support facilities						
d. Distribution		3,440	3,280	2,120	1,720	3,000
Subtotal--Maintenance	$34,650	$ 26,730	$ 26,780	$ 25,660	$ 26,540	$ 29,640
Grand Total	$67,740	$111,910	$111,800	$102,590	$106,510	$116,080

6.0 SITE EVALUATION AND COMPARISON FOR PETROLEUM CASE B

6.1 Requirements and Specific Criteria

The basic assumption for Case B is that the three existing refineries, which use crude oil as a raw material, will be expanded to meet Puerto Rico's forecast needs in accordance with their present proportion of total capacity. The facilities required would include a government-financed central crude oil terminal capable of receiving all crude requirements in excess of those presently being imported. It is further assumed that the product mix from the expanded refineries could not be made to exactly match the domestic demands, and as a result there would be a surplus of some products which would be exported. The crude import and product export volumes forecast for Case B are the same as those of Case C in which new refineries would be built near the central import site, and existing refineries would remain unchanged. The required Case C facilities would include a distribution system to move the imported crude from the central unloading terminal to the three refineries. The facilities for Case B do not include installations for accumulating and loading out the surplus products.

Berth and tank farm requirements, for each central import terminal site to be studied, were determined in 3.1.5.2. The distribution system capacities were based on the proportionate volumes of crude which the three refineries would receive.

The tentative development plans used for the cost estimates for the sites studied are shown in Figure Nos. 10 through 23.

6.2 Physical Comparison of Site Development and Distribution Systems

The crude oil terminal development of Case B would be similar at each site to the crude import installations for the Case C development. However, total land requirements and space for berths would be less than for Case C. This may be noted by comparing the tentative Case B plans on even numbered figures in the group, numbered 10 through 22, with their Case C counterparts in the group 24 through 36.

The physical features of each site for the complete tentative development for Case C are described in detail in 7.2. Reference is also made to the portions of descriptions which deal with crude import berthing facilities and petroleum tank farm areas, as well as to the even numbered Case B tentative site plans.

The odd numbered Case B plans, in the group numbered 11 through 23, show in schematic fashion the crude oil distribution systems assumed for the sites studied. These consist of pipelines from the unloading terminal site to the three crude refineries. Since all the crude is assumed to be suitable for pipeline movement, no barging would be needed except for the Isla Mona crude oil import terminal. For the reasons set forth in 5.3.1, government financed pipelines would assure the lowest transportation costs between points on the main island.

6.3 Cost and Economic Impact Comparison

6.3.1 Cost Determination

In order to obtain valid cost comparisons between the sites studied under any of the Cases of this study, and between Cases, it was necessary to use the same costing procedures and unit prices for all the capital cost and operating cost estimates involved. Therefore, the same criteria described in 5.3.1 for Case A costing were used for the Case B estimates. The pipeline distribution system was, of course, sized for handling crude oil instead of clean products, at the forecast 1985 volume levels.

6.3.2 Cost Comparisons

There are four tables at the end of this chapter entitled:

Site Comparison - Summary of Cost Government Facilities

Total Capital Cost - All Government Facilities

Capital Cost of Petroleum Port and Terminal Facilities

10-year Operating Costs for Petroleum Facilities and Barge Hire Costs

Each of these contains the prospective cost data for each site, as per the tentative development plan for Case B, so they may readily be compared.

The most significant comparison is in the first table, which contains the tabulation of total 10-year costs for each site, and hence the total revenue required for each. The least cost would be for the crude import terminal to be located at Guayanilla, and this is because the refinery located here could be served without any distribution pipeline. The cost for the terminal if located at Punta Cabullon would be very little more, for the reason that it is located very close to Guayanilla and the pipeline distances to the San Juan and Yabucoa would not be as great as from Guayanilla.

6.4 Demographic and Social Impact Comparison

As mentioned in 6.2 above, the physical features at each site are essentially the same as for the crude import facilities that would be required for the larger development plans for Case C. Thus, in a sense, the Case B development could be considered as a portion of the Case C installations. Therefore, the manpower requirements and associated requirements, such as housing, as well as disposable income, would be smaller than Case C. The relative magnitude is estimated at 80% of those mentioned in 7.4 for Case C for the petroleum port and terminal operations.

6.5 Environmental and Ecological Factor Comparison

As mentioned above, the Case B installations at each site could be considered a portion of the Case C development. Therefore, the potential environment and ecological impact would be of considerably smaller magnitude than for Case C. This would be due partly to the smaller land and water areas involved, which would result in less disruption of desirable natural features. Air pollution would be practically nil, as floating roof tanks, which essentially eliminate the escape of hydrocarbon vapors, would be used.

It must be borne in mind, however, that a major premise of Case B is the significant expansion of existing refineries. Although great strides have been made in reducing the air and other types of pollution by proper design and construction of new so-called "grass-roots" refineries, it is much more difficult and costly to attain the same results when adding to an existing plant where available land may be limited, and there is a need to maintain production during the construction. Of greatest concern from a refinery pollution standpoint would be the one in the heavily populated San Juan area.

Assuming, however, that pollution from the expanded refineries could be maintained at acceptable levels, there is a great potential pollution from other industrial processing. The forecast figures for domestic consumption used for Case B are the same as those of Case C, which are based on growing needs due to new petrochemical plants, power plants, and other industries including possibly metallurgical processing. For greatest economy in the transportation of their petroleum product needs, and the sharing of common facilities such as marine transport and power plants, these, like the corresponding entities of Case C, would tend to locate near the refineries. Technology has not yet developed to the point where all pollution from some of these processes can be controlled economically. The greatest impact would be if such industries were to be located close to the expanded refinery in the San Juan area.

6.6 Comparison of Flexibility of Future Use and Development

At any of the sites studied, reference to Chapter 7 which deals with Case C, and the associated tentative development plans for Case C, indicates it would be theoretically possible to embark on the Case B development, and then during the course of construction or shortly thereafter convert to the Case C development at slightly larger capital cost. This would be unrealistic to expect however, for Case B construction would only be undertaken following a commitment to make use of it and its pipeline system by expanding the existing refineries and proceeding with the refinery expansion construction concurrently with the Case B construction. A more logical possibility would be to proceed with Case B as assumed, and then perhaps make installations to handle the Case D level of imports and exports, with new refineries constructed at the selected site, of suitable capacity to handle the additional volumes of export products which are in excess of the Case B volumes indicated in 3.1.5.1. In effect, this approach would be a combination of Case B, and a modified version of Case D which per se, is based on no increase in the present refineries.

SITE COMPARISON
SUMMARY OF COST OF GOVERNMENT FACILITIES
CASE B--1985

(Dollars in Thousands)

Site	Capital Cost	Rank	10-Year Operating Cost	Rank	Total 10-Year Cost	Rank	Average Annual Cost	Rank
1. Aguadilla	$162,929	6	$225,800	5	$388,729	5	$38,873	5
2. Añasco/Rincón	148,700	5	213,010	3	361,710	4	36,171	4
3. Punta Cabullon	130,355	1	192,740	2	323,095	2	32,310	2
4. Guayanilla	131,000	2	190,260	1	321,260	1	32,126	1
5. Jobos	143,860	4	216,400	4	360,260	3	36,026	3
6. Mona	143,240	3	580,140	7	723,380	7	72,338	7
7. Arecibo	315,370	7	344,860	6	660,230	6	66,023	6

TOTAL CAPITAL COST
ALL GOVERNMENT FACILITIES
CASE B--1985

(Dollars in Thousands)

	Aguadilla	Añasco/Rincón	Punta Cabullon	Guayanilla	Jobos	Mona	Arecibo
1. Petroleum terminal	$110,429	$ 98,900	$103,155	$106,600	$115,260	$130,240	$263,870
2. Petroleum industrial site	--	--	--	--	--	--	--
3. Support facilities	--	--	--	--	--	9,000	--
4. Distribution pipeline	52,500	49,800	27,200	24,400	28,600	--	51,500
5. Distribution barge terminals	--	--	--	--	--	4,000	--
Total	$162,929	$148,700	$130,355	$131,000	$143,860	$143,240	$315,370

CAPITAL COST OF PETROLEUM PORT AND TERMINAL FACILITIES
CASE B--1985

(Dollars in Thousands)

	Aguadilla	Añasco/Rincón	Punta Cabullon	Guayanilla	Jobos	Mona	Arecibo
1. Land acquisition a. Land	$ 2,000	$ 2,500	$ 3,500	$ 2,500	$ 3,500	$ 250	$ 800
b. Landfill	--	--	--	--	--	--	15,000
2. Dredging and navigational aids	500	500	500	500	500	500	128,000
3. Berths a. Crude import	39,000	24,000	24,000	30,000	24,000	39,000	30,000
b. Crude to Main Island	--	--	--	--	--	16,000	--
4. Trestle lines to shore	525	5,000	7,700	5,700	18,225	3,500	1,650
5. Tank farm and piping	48,000	48,000	48,000	48,000	48,000	48,000	48,000
6. Service craft	5,000	5,000	5,000	5,000	5,000	5,000	5,000
7. Service harbor and miscellaneous	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Subtotal	$ 96,025	$ 86,000	$ 89,700	$ 92,700	$100,225	$113,250	$229,450
8. Engineering and administration (15%)	14,404	12,900	13,455	13,900	15,035	16,990	34,420
Total	$110,429	$ 98,900	$103,155	$106,600	$115,260	$130,240	$263,870

10-YEAR OPERATING COSTS FOR PETROLEUM FACILITIES AND BARGE HIRE COSTS
CASE B--1985

(Dollars in Thousands)

	Aguadilla	Añasco/Rincón	Punta Cabullon	Guayanilla	Jobos	Mona	Arecibo
1. Interest cost							
a. Port and terminal	$ 36,800	$ 32,960	$ 34,380	$ 35,530	$ 38,420	$ 43,240	$ 87,950
b. Industrial site	--	--	--	--	--	--	--
c. Support facilities	--	--	--	--	--	3,000	--
d. Distribution	17,500	16,600	9,070	8,130	9,530	1,330	17,170
Subtotal-- Interest cost	$ 54,300	$ 49,560	$ 43,450	$ 43,660	$ 47,950	$ 47,570	$105,120
2. Operating cost							
a. Port and terminal							
. Labor	$ 35,800	$ 35,800	$ 39,000	$ 39,000	$ 42,200	$ 42,200	$ 32,600
. Consumables	9,000	9,000	9,800	9,800	10,600	10,600	8,200
b. Support facilities							
. Labor	4,200	4,200	4,700	4,750	5,000	5,000	3,750
. Consumables	12,800	12,800	14,300	14,250	15,000	15,000	11,250
c. Distribution							
. Labor	13,200	12,670	7,180	6,190	9,690	1,150	12,510
. Consumables	30,800	29,570	16,750	14,430	22,610	2,800	29,190
. Barge hire	--	--	--	--	--	387,200	--
Subtotal-- Operating cost	$105,800	$104,040	$ 91,730	$ 88,420	$105,100	$463,950	$ 97,500
3. Maintenance							
a. Port and terminal	$ 55,200	$ 49,450	$ 51,580	$ 53,300	$ 57,630	$ 65,120	$131,940
b. Industrial site	--	--	--	--	--	--	--
c. Support facilities	--	--	--	--	--	2,700	--
d. Distribution	10,500	9,960	5,980	4,880	5,720	800	10,300
Subtotal-- Maintenance	$ 65,700	$ 59,410	$ 57,560	$ 58,180	$ 63,350	$ 68,620	$142,240
Total	$225,800	$213,010	$192,740	$190,260	$216,400	$580,140	$344,860

7.0 SITE EVALUATION AND COMPARISON FOR PETROLEUM CASE C

7.1 Requirements and Specific Criteria

Case C assumes a new crude oil import facility, plus a new refining center plus new internal product distribution systems plus export facilities for excess products. It is further assumed that there will be no increase in capacity at any of the three existing refineries which use crude oil as a raw material. Although it would also be possible to install a distribution system to move crude from the new import facility to these refineries, this has not been included in Case C development in this study.

From the preliminary screening, seven terminal sites were selected that appeared to have land areas nearby that would be suitable for industrial development. Tentative development plans were prepared on which to base the cost estimates of this study. The assumed land area requirements are contained in 3.5. The plans are shown on Figures 24 through 37.

Berth and tank farm requirements were determined in 3.1.5.2.

The distribution systems for products produced at the new refining center which are destined for internal consumption were assumed to move these products, in proportion to their estimated requirements, to the approximate centers of the three principal consuming areas, i.e., near San Juan, Ponce and Mayaguez. Major alternate methods of distribution which were given consideration are shown in the odd-numbered figures in the series numbered 25 through 37. As mentioned in 7.3, the distribution systems for all sites on the main island would consist of pipelines for the "clean" products, supplemented by barge hauling of the #6 and other heavy fuels. Barge transport from the Isla Mona site to the main island has been assumed.

7.2 Physical Comparison of Site Development and Distribution Systems

The following sections contain information on the physical features of the seven sites studied. This is partly in explanation of the tentative development plans, and partly information that could not be shown on them. As mentioned in 7.3, the distribution systems for all sites on the main island would consist of pipelines for the "clean" products supplemented by barge hauling for the "dirty" #6 and other residual fuels. For the site on Isla Mona, barge hauling of all products would be necessary.

7.2.1 Arecibo (Figures 24 and 25)

The site at Arecibo is government-owned land just east of the city in the area designated Caño Tiburones. Heavy seas on the north coast preclude berthing offshore so the port would be in a sheltered basin to be dredged in the Caño area.

The Caño Tiburones is a former marine slough approximately nine square miles in area. Canals have been constructed throughout and the water table is at the same level as the canal water level. Much of the area is below sea level. Due to springs in the area, the water ranges from fresh to diluted sea water.

The VLCC berths would be located in a dredged basin which is connected to the sea by a 1,000-foot channel. The channel is so located that a breakwater would probably not be required. The basis would be dredged to elevation -95 and the channel extended to the 120-foot contour. A turning basis would also have to be provided.

Further in from the crude berths and served by a new channel would be the product berths as well as possibly dry cargo and container-ship berths, all to be dredged to the indicated depths.

Adjacent to these dredged basins would be the tankage area and possible other areas for development of a petroleum complex and a metallurgical complex on new land built up in the swampy portions by using the dredged material. However, the swampy soils in the area are approximately 10 feet thick and would require stabilization after placement of the fill, before building the facility structures.

At present, the land is almost completely uninhabited. Some land has been reclaimed and filled and is being used for agricultural purposes.

7.2.2 Jobos (Figures 26 and 27)

The Aguirre-Jobos area is located in Jobos Bay on the southeast coast of Puerto Rico and is part of the region which includes the municipalities of Salinas, Guayama, Arroyo and Patillas.

The coastal plains in this region have historically been oriented toward the growth of sugar cane, but in the last few years a refinery for processing unfinished petroleum products and an associated petrochemical complex in Guayama have significantly changed the area. Two fossil-fuel power plants are under construction and are the nucleus of a proposed industrial complex.

The Jobos area is similar to the Punta Cabullon and Mayaguez areas in that a submarine shelf at the six to ten fathom depth exists for considerable distance offshore. Reefs, quiet water and marine life associated with these shallow shelves abound in the area. At the Jobos area, the shelf is approximately six miles wide and would require submarine pipelines extending almost eight miles out to sea in order to service crude berths at the 120-foot contour. More shoal areas are even further offshore and would have to be designated by navigation aids. The VLCC berths are shown as having berths on both sides of the structures.

Petroleum product berths are shown at the 60-foot contour and would also be connected to shore by submarine pipelines. Possibilities for expansion of berths would be good at both locations.

Tank farms for crude and products are shown adjacent to Puerto de Jobos in the Bahia de Jobos. The proposed industrial complex is shown to the west and north of the tank farms while the metallurgical complex is to the east of the tank farm areas. These areas have been selected to minimize relocation of population.

A possible bulk storage area is shown to the east of the existing refinery at Guayama. Dry cargo berths and a container-ship port could be located in a dredged area adjacent to the refinery which is now a mangrove swamp. Access would be by channel dredged to 40 feet. Breakwaters are not required because of natural shoals and reefs.

7.2.3 Punta Cabullon (Figures 28 and 29)

The site at Punta Cabullon is just to the east of Ponce, Puerto Rico's second largest city. The deep-water berthing area is located northwest of Isla Caja de Muertas and is protected by that island and a reef system extending northeast. This area is one of the few locations in Puerto Rico where VLCC single-point moorings (SPM's) would be feasible.

The VLCC berths are shown as either an offshore platform with berthing on both sides or two SPM's. Both types of berthing facilities would be served by submarine pipelines. Final decision on the type of berthing facility would depend on further studies. Presently, opinion favors the platform berths because of the shorter submarine pipelines, greater safety and future expansion possibility adjacent to the first platform.

The product berths are shown close inshore without a breakwater. This is believed feasible, but their alignment might be different to better conform to direction of seas. The product berths are close enough to shore for a trestle connection.

A breakwater-enclosed dry bulk cargo and container-ship harbor is shown. It is probably the dry bulk ships could be safely berthed outside the harbor, in which case the harbor size could be reduced and its depth reduced to 40 feet sufficient for container ships.

A general cargo harbor is shown inside Punta Cabullon itself with a groin breakwater for protection. This would also be the site of the service harbor.

The land for tank farm and industrial facilities is contiguous to the shore. Most of the land is agricultural, with some zoned industrial. It is almost uninhabited except for a small settlement on the beach. Foundation conditions are expected to be good.

Electric power is barely adequate at present, with serious outages experienced from time to time. Some improvement is in store as new generating units are being completed in the nearby power plants. However, any major new industrial facility would require an additional power plant.

7.2.4 Guayanilla (Figures 30 and 31)

The site is close to the largest single existing oil refinery and to the majority of the petrochemical plants presently operating in Puerto Rico. The existence of present industry and the environmental requirements that these facilities be brought up to standards by 1974 lead to the belief that additional development in this area might be possible.

The petroleum tank farm area and the industrial complexes would be located in shorefront areas bordering the westerly shoreline of the Bahia de Guayanilla. These areas were chosen because they represent the only available land that is not presently residential or industrial. Even so, quite a few people would have to be relocated. Dredging and the creation of new land would be required for the Case D development. Areas for flood protection must be reserved.

A shoal area exists offshore at about the five-fathom contour and corresponds to a previous level of the oceans. It is not nearly as extensive as at Jobos, Punta Cabullon and Mayaguez.

The 120-foot contour is about 9,300 feet from shore and just beyond it is a steep cliff-like dropoff. The VLCC crude import berths would be one-sided structures near the edge of this cliff, connected to the shore by submarine pipelines.

The existing berths for the Corco refinery are on the eastern side of Bahia de Guayanilla.

The product export berths could be located on the west side of the narrow entrance to the Bahia. To install the total of four berths required for the estimated 1985 development of Case C, some dredging would be necessary, but not an excessive amount. This would also provide a ship turning circle.

The possibility of a pier with two berths for bulk cargo ships in the deep-water basin south of Punta Verraca is indicated on the tentative development plan.

No dry cargo and container berths are shown for the Guayanilla site.

7.2.5 Añasco/Rincón (Figures 32 and 33)

On Figure 32 are shown two possible arrangements for the VLCC crude import berths. These might be finger piers in the Bahia de Añasco, or single-side berthing structures south of Rincón, along the 120-foot contour. Considerable care would be required in the structural design and construction because of the cliff-like limestone sea bottom. Benching of the underwater rock might be required. For these reasons, the location in the Bahia might be preferable. In either arrangement, the piers would be served by submarine pipelines.

The product tanker berths are shown as finger piers north of the VLCC berths. If a breakwater harbor were provided, the tanker piers could extend out from it. If not, a head trestle would be provided. There is space enough to provide several times the number of required berths with little or no dredging. No special construction problems are anticipated.

Possible dry bulk cargo berths are shown outside the breakwater, which would be feasible at this location. The breakwater would be advisable for container ships and general dry cargo operations based on present knowledge of conditions. As is the case with several of the other sites studied, dredging would be required in the protected habor area. There is a possibility that it could be less extensive than shown. Thus, while it is possible to locate this type of facility at Añasco, we do not think it the best site for it, and do not recommend it. If this portion of the development were eliminated, no dredging would be required, but a protected area for service craft would have to be provided.

The tank farm and industrial area are contiguous in the river flatlands immediately behind the shore. Most of the land is used for growing sugar cane, and the pieces shown are almost completely uninhabited. There is ample land available for the facilities shown, and some possibility, but no certainty, of additional land south of the Rio Grande de Añasco.

The area for the proposed facilities is flat and subject to flooding from the river, but can be protected. The upper soils are soft and organic, but good bearing soils are at reasonable depths. No especially difficult or unusual foundation conditions are expected.

The land shown for the alternate tank farm site near Rincón is similar, but limited in available area. Also, it would be more difficult to protect from flooding.

7.2.6 Aguadilla (Figures 34 and 35)

The VLCC berths are shown north of the town, along the 120-foot contour. The bottom is steeply shelving at this location and single-side berthing structures must be used. The berths would be located less than 1,000 feet offshore and would be connected to shore by trestles. Whether submarine pipelines to shore or lines supported on the access trestles would be used would depend on the exact locations selected for berths and receiving tankage. Considerable care would be required in the structural design and construction of the berths because of the cliff-like limestone sea bottom. Benching of the underwater rock might be required. The VLCC berths would be oriented to minimize ship motion from seas refracted around Punta Borinquen. They would be located to maximize the protection of Punta Borinquen and allow sufficient maneuvering room for approaching the berths. Probably only two VLCC berths could be constructed at this site, although further study of the wave action might show that more could be built.

Berths for product tankers are shown either within a breakwater harbor, if it were provided, or outside with trestle connection to shore. It is also possible to orient the product berths along the 60-foot contour south of the VLCC berths. This would result in single-side berthing structures and would possibly use more shore area, but reduce loading line length. The technical feasibility would depend on just how waves are refracted around Punta Borinquen. In either case, the berths outside the harbor would be directly offshore from the town and possibly closer than is desirable.

The breakwater-enclosed harbor might be necessary for product tanker berths. It would certainly be required if other port facilities, such as bulk berths and container-ship berths, were added to the petroleum requirements.

Trade wind seas refract around Punta Borinquen. Heavy seas for considerable periods of time have been reported off the town of Aguadilla. If this is so, breakwater protection would be required, although this might be lessened if the berths can be oriented with ships facing into the seas. Further study is required.

Except for the breakwater harbor shown and the possible rock benching for VLCC berths, no major dredging is contemplated.

The tank farm is shown north of the berths in a relatively lightly populated area. The tank farm would be on two levels, the lower along the narrow beach and the upper on the plateau about 150 to 200 feet above sea level.

The area to the north of the tank farm, also on two levels, is available for industrial installations. About 700 acres might be used, some of it populated. An impediment is the Ramey air strip glide path which limits the height of structures and stacks.

Other industrial land requirements could be met by tracts that are further inland and non-contiguous. Considerable land is available, some of it lightly populated or uninhabited. The terrain is relatively high, rolling and well drained. The geology is classified as Karst limestone. Caverns are numerous.

Electric power is inadequate at present, so any large industrial development would have to be served by a new power plant.

7.2.7 Isla Mona (Figures 36 and 37)

Isla Mona presents one of the best potential large industrial sites in Puerto Rico because of the abundant unused real estate and the island's limitless possibilities for future expansion of refinery capacity. A development along the south coast of the island would be protected from the trade winds and from the heavy seas of northeast origin, and has been assumed in this study.

On the tentative development plan, berthing facilities are shown along the south coast with breakwater protection at Punta Caigo o no Caigo and Punta Oeste. The results of a bathymetric and sub-bottom survey indicate rough topography underwater with steep dropoffs and cliffs. Because of this bathymetry, the VLCC berths could only be on one side of the berthing structures. The first two berths would be within 600 feet of shore and future ones would be slightly more offshore. Access to land would be by trestles. Whether submarine pipelines to shore or lines supported on trestles would be preferable would depend on final locations of the piers and receiving tankage. As at Aguadilla, great care would be required in structural design and construction of berthing facilities because of the cliff-like nature of the limestone sea bottom. Benching would probably be required at the berths.

Product berths and possible dry bulk cargo berths are shown adjacent to the Punta Oeste breakwater. These are finger piers within an area dredged to 60 feet. Behind these product berths, service craft would be moored in a protected harbor dredged to 20 to 30 feet below mean low water.

Possibly dry cargo berths might also be located behind the breakwater. Container-ship facilities were not considered because of the isolation of Isla Mona from the rest of Puerto Rico, although if the island were to become highly developed container transport might become important for imports and exports.

A port industrial area consisting of a power plant, desalinization plant, waste disposal and similar municipal facilities could be located in the low coastal area adjacent to the cliffs or the upland plateau.

Most of the island is a limestone tableland and the proposed tankage area, metallurgical complex, bulk and product storage, petroleum industrial complex would all be located on the limestone plateau.

An airfield could be located in the northwest corner of the island while a residential and recreational zone is shown on the tentative plan in the northeast corner. The proposed scheme leaves thousands of acres as a wildlife preserve and a buffer zone.

7.3 Cost and Economic Impact Comparison

7.3.1 Cost Determination

The same existing procedures and unit prices used for the capital and operating cost estimates of Case A, which are explained in 5.3.1, were used for determining Case C costs.

The Case C capital cost and operating costs include those assumed to be furnished by the government, such as the land and the support facilities, including a power plant, water supply system, common waste treatment facilities and other things such as common use roads. All the industrial buildings, processing equipment and other plant requirements have been assumed to be planned, financed, constructed and operated by private companies.

As with all the other Cases of this study, the terminal and the distribution system for each site have been sized for the forecast 1985 volume levels.

For the reasons set forth in 5.3.1, government-financed pipelines would assure the lowest transportation costs for the "clean" products for all the main island sites, with barges used only for the #6 and other residual fuels.

7.3.2 Cost Comparisons

There are five tables at the end of this Chapter 7 entitled:

- Site Comparison--Summary of Cost of Government Facilities
- Total Capital Cost--All Government Facilities
- Capital Cost of Petroleum Port and Terminal Facilities
- Capital Cost of Petroleum Industrial Site
- 10-Year Operating Cost for Petroleum Facilities and Barge Hire Costs

Each of these contains the corresponding cost data for each site as per its tentative development plan for Case C, so they may readily be compared.

The first table compares the total capital and operating costs for the 10-year period of the study, from 1976 to 1985, that would be involved, equivalent to the total revenue required for each site.

The least cost would be for the Añasco/Rincón location, but this is only about 1% lower than for Punta Cabullon. The total costs for Guayanilla, Aguadilla and Jobos rank third, fourth and fifth in that order, the latter being about 10% greater than Añasco/Rincón. The dredging and landfill that would be needed at Arecibo, as anticipated, make the total cost extremely high, almost 67% greater than Añasco/Rincón. Total cost for Isla Mona site, which ranks sixth, is about 20% greater than Añasco/Rincón. The reason for part of the difference is that the product distribution distances are much greater than for any main island site, and barge movements in privately owned and operated barges have been assumed in accordance with the criteria of 3.1.5.3, whereas for the main island sites, distribution of all but heavy fuels would be by government owned and operated pipelines, as stipulated in 3.1.5.3.

If the barges were to be owned and operated by the government, the estimated barge haul costs for all sites would be approximately 16% less than those shown in the last table of this chapter. On this basis, the total 10-year cost for the Isla Mona site would be reduced by about $15.4 million, but it would still rank sixth.

7.4 Demographic and Social Impact Comparison

7.4.1 Arecibo

The population of Arecibo is 73,500 as reported in the 1970 census. The city of Arecibo has a port, and highway access in the area is good by Route 2. An airport is just south of the Caño. Present land use is overwhelmingly agricultural, but sizable industrial developments are being considered in the Manati-Barceloneta area to the east.

The city of Arecibo has three registered historic sites, but these are not in the Caño area. There are no other natural landmarks of significance.

7.4.2 Jobos

The 1970 census showed the population for the tributary area to be 89,000. Unemployment is slightly in excess of the Puerto Rico average. All arable land is used for sugar cane while the hills to the north are used as dairy farm areas. In addition to the activities in the petroleum/petrochemical complex, sugar cane is processed in this area.

7.4.3 Punta Cabullon

The Municipios of Ponce, Peñuelas and Juana Diaz from which the site is readily accessible had in 1970 a population of 211,000, with the vast majority of this within the city of Ponce whose geographical center is about four miles northwest of the terminal site.

Unemployment is somewhat below the average for the western region, but is high in nearby areas. Industry is varied in the area, with Puerto Rico's major oil refining and petrochemical complex located about 12 miles west of the site.

There is a commercial port at Ponce about two miles away. Highway access is good. There is a commercial airport just to the north of the site.

7.4.4 Guayanilla

The combined population of the Municipios of Yauco, Guayanilla and Pañuelas was 69,000 according to the 1970 census. This area of Puerto Rico is one of the most industrially developed on the island outside of San Juan and has a 17-year tax exemption. Unemployment is believed to be slightly higher than in other parts of the island.

Land use in the vicinity of Guayanilla is approximately 50% industrial. Another 30% is forest land, and less than 1% is agricultural.

7.4.5 Añasco/Rincón

The total of the 1970 census populations for the Municipios of Añasco, Rincón, Aguada and Mayaguez is 140,000, with approximately half in the city of Mayaguez, the center of which is approximately six miles south-southeast of the terminal site.

The unemployment rate is above the island average, but about average for the western regions. Industry is mixed. Agriculture is still an important activity, but decreasing in importance.

There is a commercial port at Mayaguez. Highway connections are good to the rest of the island. A commercial airport is just south of the industrial site.

The shore in the area is classified for bathing and industrial purposes. There is a popular recreational beach at the village of Tres Hermanos and Coral Gardens at Punto Cadena. It is believed that development could avoid encroachment of these areas.

7.4.6 Aguadilla

The 1970 census gave the regional population as slightly over 100,000, with nearly three-quarters rural. Unemployment is about twice the average and is compounded by the closing of Ramey Air Force Base. Existing industry is classed as light.

There is a four-lane highway to Mayaguez and San Juan.

The shoreline classification in the area shown for development is for bathing and propagation of fish. Land use is residential and recreational. Inland, the land is agricultural.

No important tourist facilities exist in the area shown for development. Some do exist further to the west on the north shore of Punta Higuera. The beach there has great potential for recreational use.

7.4.7 Isla Mona

Since there is no population on the island except for the police, Department of Natural Resources personnel, and Coast Guard personnel, there are no utilities on the island. Development of all requirements of this kind would have to be undertaken.

The island is a tourist attraction but is not visited frequently because one must have a large pleasure craft and a supply of water must be brought along. Most visitors are hunters and day picnickers. The island has recently become the subject of intense scientific investigation and study.

A number of archaeological finds have been made on the island associated with the Taino Indians. A number of historical relics also exist.

7.5 Environmental and Ecological Factor Comparison

7.5.1 Arecibo

Because of salt-water intrusion, there are no potable water wells in the Caño area. High yields are obtained, however, from wells in the alluvium of the Rio Grande de Arecibo and Rio Grande de Manati valleys. Potentially, production of well water could be increased, but care would be necessary to prevent salt-water intrusion. An alternate would be to bring water by aqueduct from the higher valleys to the south.

Numerous beaches dot the shore along the north coast east and west of Arecibo. A small stretch of beach would be destroyed by the channel.

Rainfall in the Arecibo area is in excess of 50 inches per year with six inches during the month of May.

The winds are typical for the north coast, dominated by the trade winds with a secondary effect onshore during the day and off shore at night. The highest mean temperature recorded was 81°F; the lowest was 71°F. The mean temperature recorded was 77°F.

Ocean currents flow from east to west along the coast and heavy seas during the winter are common for the entire north coast.

Information on marine ecology is not presently available for this particular location, but is assumed to be similar to other north coast sites.

The sandy beach, rocky shore, sand bottom, hard bottom and deeper areas all have their ecosystems consisting of crabs, algae, sponges and encrusting corals. There are no mangroves on the shoreline. Coral formations are known to exist offshore.

7.5.2 Jobos

The south coast of Puerto Rico has considerably less rainfall than the north coast. The average rainfall for the Aguirre area is 42 inches and the maximum monthly rainfall was 6-1/2 inches. The highest mean temperature is 84°F while the lowest is 75°F.

There are no rivers in the Jobos area and water supply is from wells. The alluvial deposits are thickest near the Bahia and the coarse sand and gravel are the principal water-bearing materials throughout the south coastal region. Wells with large yields are common. However, unless the aquifiers are sufficiently recharged by local rain water or by river flooding, declining water levels would cause a decrease in yield per well. The available data on water level and quality of water indicate that ground water supply has not been overdeveloped to date. The total underground discharge to the sea from these aquifiers is 130 mgd and as much as one-half might be developed as a ground water supply.

The winds at Jobos are typical of land-sea breeze phenomena at other parts of the south coast of the island and onshore produce low-level winds during the day with reversal at night.

The Jobos area consists of coarse-grained sedimentary rocks such as sandstone and siltstone which have been extensively weathered to depths of from 10 to 70 feet below the surface. Alluvial deposits are prevalent and consist of weathered remnants carried from the north by flooding streams and rivers.

Both the oceanic and the coastal current offshore of the Aguirre-Jobos area are westerly and do not exceed 0.5 knot which is negligible. The lowest water temperature recorded was 25°C and the highest 30°C (86°F), the latter during September.

The south coast of Puerto Rico is classified as a subtropical dry forest. However, since all suitable land has been cleared for cultivation, there is no natural vegetation except for mangrove forests occupying swamps and tidal flats. There are over 2,000 acres of mangroves in the Jobos Bay area. The largest undisturbed natural mangrove and estuarine area in Puerto Rico is just to the west of Jobos Bay. There is essentially no wildlife associated with the cultivated lands. Rats and reptiles inhabit the mangrove areas.

Turtlegrass beds predominate in shallow water. Other flora are mixed in the beds.

Fringing reefs along the seaward side of Jobos Bay occupy approximately 850 acres. All types of coral species are present in these waters.

7.5.3 Punta Cabullon

The land is very level. The shore is classified as suitable for propagation of fish.

Rainfall is less than 40 inches per year.

The winds are moderated by the land mass to the north and east. While the winds have the general east to west flow of the trade winds, they are much lower in velocity and strongly influenced by the land-sea breeze effect. During the day, the pattern is wind from the southeast and at night from the northeast. Because the center of the city of Ponce is only about four miles northwest of the site, extreme precautions to eliminate air pollution from the industrial activities would be necessary.

Ocean currents flow from east to west but are reported to be weak. Sea conditions are generally mild except for the phenomenon of "mar desbordada."✓

Fresh water is scarce in the area. A sea-water evaporator plant would be required for the industrial facility unless a new aqueduct system from the northern mountains were installed.

New waste disposal facilities would have to be installed for the new industrial installations. The offshore water is relatively unpolluted. Ecological data are scarce. There are no mangroves, but a number of coral outcroppings exist. Recreational areas include small beaches at the site and on Isla Caja de Muertas. It would appear possible to protect both from pollution. The greatest water pollution danger would be from oil spillage drifing westward.

7.5.4 Guayanilla

Ponce, only a few miles east of the Guayanilla site, is the nearest location for which good weather data are available. Normal annual precipitation in the Ponce area is 34 inches. A maximum mean temperature of 83°F was recorded at Ponce and the minimum mean temperature was 79°F.

North of Guayanilla, the foothills of the West Central Mountains are mostly limestone and known locally as the Ponce limestone formation. Guayanilla is located in the flood plain of the Guayanilla River. The flood plains of the Guayanilla, the Yauro and the Macana Rivers merge to form an alluvial fan which is 4.5 miles long and one mile wide along the coast. There are also limestone outcrops adjacent to this plain.

The Yauro River is subject to flooding from the mountain rains and the developed area would require protective dikes. North of Guayanilla, the entire base flow of the river is diverted by a series of dams and spread over the land by irrigation ditches.

Water supply in the Guayanilla area is obtained from wells in the alluvium of the river valleys. The average yield of wells in the area is 1,100 gpm. The alluvium has a saturated thickness of 100 feet over the area. The total water in storage is estimated to be 72,000 acre-feet. An analysis of the aquifer water balance indicates a mean annual recharge in the range of 16,000 acre-feet. About one-quarter of this involves recirculation of irrigation. Serious water shortages have been reported in this area due to low rainfall.

The offshore regime at Guayanilla consists of much reef and back reef shallow areas. Two old river courses break up these shallows. Reefs protect the entrance of the Bahia de Guayanilla which is one of the best natural harbors on the island.

The alluvium deposits from the rivers undoubtedly continue offshore, particularly close to land. Sedimentation probably decreases in deeper water. Seaward of the 120-foot contour, the bottom drops off at a steep angle.

The surface ocean currents off Punta Verraco are toward the southwest with a velocity of 0.4 knots. Water temperature averages 27°C (81°F).

A preliminary marine life survey at Punta Verraco showed the crustaceans to be copepods for the most part. Algae were found in Guayanilla Bay. The coral reefs and thalassia beds of the area are quite healthy. All major reef fish species have been observed.

Seven miles west of the site are places of historical and cultural value. Ponce's cathedral is 10 miles east of the site.

7.5.5 Añasco/Rincón

Generally speaking, Añasco Bay presents one of the best protected deep-water port sites in Puerto Rico. Punta Higuera to the north gives almost complete protection from the trade winds, and the more northerly seas and swells. A reef and shoal system extending off Mayaguez to the south gives protection from the southwest. Only rare westerly or hurricane seas would cause difficulty.

Although prevailing winds are easterly and thus normally blow toward the sea, there is a pronounced land-sea breeze effect which causes onshore winds of low to moderate velocity during a significant portion of the year. It is not known to what altitude this effect extends and whether or not a tall stack to pierce the trade wind layer would be feasible. This is recommended for investigation.

The ocean currents in the Bahia de Añasco are weak, with a general trend to flow north under the influence of the currents in Mona Passage. At the tentative development site, weak surface currents have been noted to flow east and west with the tide. A report of water temperatures indicates an upwelling of colder water close to shore. This would indicate a general flow of surface water outward to the west. While the currents would have little or no effect on navigation or ship berthing, the apparently conflicting data indicate further study is required for environmental studies.

Rainfall in the area is about 80 inches per year.

Fresh-water supply is presently adequate, with good potential for development of both surface and ground water. Electric power is reported as adequate, but will require a substantial addition for a large industrial complex.

Waste disposal and sewer facilities are presently barely adequate. The harbor at Mayaguez is polluted as is the Rio Añasco. New facilities are required for the proposed plants.

No important ecosystems are reported. A small grove of mangroves exists at the mouth of the Rio Añasco.

7.5.6 Aguadilla

Rainfall in the region is between 60 and 70 inches per year. Trade winds predominate, with relatively slight land-sea breeze effect. The shore is mostly rocky with very narrow or non-existent beaches to the north, but wider to the south, especially west of the Rio Culebrinas. Ocean currents are less than 1/2 knot, generally flow from north to south and from east to west. There is littoral drift from north to south.

The Rio Culebrinas enters the bay south of the town. This river is polluted and carries a heavy silt load. It is subject to frequent flooding. A training groin to reduce the silt and pollution flowing into the breakwater harbor would be necessary.

Present fresh-water supply is adequate for the town, but would require a considerable increase for heavy industrial development. There is little hope for doing this by ground water in the region. A large increase in water supply would require an aqueduct from reservoirs to the east.

Sanitary sewers are inadequate. For the most part, municipal liquid wastes are dumped without treatment.

No important ecosystems are reported, either terrestrial or marine. There are no significant mangrove areas in the vicinity.

7.5.7 Isla Mona

Mona has a semi-arid climate with slightly in excess of 30 inches of rain per year. Winds are predominantly from the east and northeast, since there is no land-sea breeze pattern due to the small size of the land mass.

The upland plateau of the island comprises most of the land area and consists of Isla Mona dolomite and Lirio limestone. At one point, 80 meters of dolomite are exposed in the cliffs on the northern side of the island.

The Lirio limestone is more fossiliferous and solution pitted than the dolomite, and forms a cap over the dolomite. The Lirio has its maximum thickness along the southern cliffs and is 40 meters thick here. There are caves along the southern cliffs, and small solution cavities are abundant.

The coastal lowlands are composed of reef limestone, beachrock and beach deposits. Only a very thin soil mantle covers the reef deposits and in many areas there is no soil cover. Soil and sand fragments are calcareous and derived from shells or other organisms.

The absence of a potable water supply has hindered development of the island and during periods of low rainfall, the native animal population is severely threatened. At the few present habitations, most of the water used is that collected by roof catchments and stored in barrels. Visitors to the island are warned to bring their water supply. There are a number of wells in the coastal lowlands, but they are brackish and not used for drinking.

Bathymetry around the southern portion of the island was determined by survey for the present report. Small sea island shelves at the 6 to 10 fathom depth surround the southwest and southeast coasts. Beyond these shelves, the sea bottom drops off steeply to greater than 350 feet.

The marine currents flow in a northwesterly direction along the northeastern coast of Mona bending toward the west and passing between Mona and Monito. Along the southern coast, the current flows in a westerly direction. Waves are related to the trade winds and these hammer the northern and eastern coasts where the cliffs absorb the energy. There is little wave action on the southern coast, although full data are not available. Littoral drift is minimal, most being accumulated at Punta Oeste.

Mona supports 390 species of flora of which 25 are unique. The flora is xerophytic, composed of cactus, leguminous plants, shrubs and dwarf trees.

A number of endemic species of fauna also thrive on the island, including spiders, snakes, lizards and turtles. There is a substantial population of feral cats, rats, mice, goats and pigs whose ancestors arrived on various occasions since early colonial times. There are conflicting opinions regarding the abundance of fish in the reef areas.

There is great opposition to industrial development of Mona on the part of Puerto Rico's professional environmentalists and scientific community. This is mostly for the same reason it is attractive for such development. It is the largest tract of uninhabited, government-owned land in Puerto Rico. Development of Mona presents a classic clash of environmental and social values. There is a question as to whether or not a compromise could be achieved.

7.6 Flexibility

7.6.1 Arecibo

If it were built, Arecibo would have flexibility for dry bulk and container operations. There would be little other flexibility. It rates low on this factor because of the great amount of dredging required for any alterations.

7.6.2 Jobos

Jobos rates low because of exposure to active sea conditions outside of the bay areas and extensive dredging required inside. It does have flexibility for non deep-water port activity.

7.6.3 Punta Cabullon

With the exception of limitations due to potential air pollution drifting over the city of Ponce, the center of which is about four miles northwest of the site, this is the most flexible location examined. Ample areas of very suitable land, a good shore front and nearly ideal offshore conditions give an excellent degree of flexibility of layout and operation. Aside from the aforementioned pollution aspects, nearly any type of industry could be operated in conjunction with the petroleum industry. This site must be rated first in flexibility.

7.6.4 Guayanilla

Guayanilla rates well for dry bulk cargo handling and metallurgical industry potential, but not for other non-petroleum facilities. For instance, the Case C land requirements for the petroleum and metallurgical facilities and bulk cargo would develop all available land with none left for dry cargo handling. Also, in order to develop to the Case D level of activity, new land would have to be made by expensive dredging.

7.6.5 Añasco/Rincón

Full development to the Case C level is possible, although, as noted in 7.2.4, the container-ship and general dry cargo berths would require dredging. By development of the alternate site at Rincón, the Case D level could be reached. If it could be established that more land could be obtained south of the Rio de Añasco, there would be even greater flexibility for arranging the Case D installations.

7.6.6 Aguadilla

If a breakwater were found necessary for the product berths, dry bulk cargo and container berths could be added at little additional cost. The cost and availability of land would be a detriment, as would access from the berths to the inland industrial sites. Installation of metallurgical industries in the Culebrinas Valley would have considerable potential adverse impact on air and water quality in the Aguada to Punta Higuera recreational area and is not recommended. Substitution of a small steel mill for the petroleum industry at Punta Borinquen might be feasible if it did not interfere with operation of the Ramey air strip. This would block part of the petroleum installation. In the early stages of development, combination dry bulk cargo facilities could be installed on the VLCC berths, but in later stages this would result in serious interference with petroleum operations. In sum, Aguadilla could be developed for non-petroleum use, but is not very flexible for combination use.

This site is extremely limited in potential for future expansion possibilities. The limited suitable space for berthing facilities, the problems with land acquisition, and non-contiguous, inland locations for all but the minimum industrial facilities constitute an impediment to future expansion to the Case D level or flexibility of use.

7.6.7 Isla Mona

Mona rates poorly for container port, shipyard or general port, except for its own requirements. It rates as one of the highest for development of other heavy industry, such as metallurgical, with almost unlimited room for expansion. It also presents an excellent potential for a very large oil-fired thermoelectric plant fed by cheap residual fuel from adjacent large refineries. The power generated could be transmitted economically by submarine cable to the main island. Development of Mona also presents a chance both to urbanize an uninhabited portion of Puerto Rico and to establish laws and regulations to protect endangered fauna from molestation by hunters and careless visitors.

SITE COMPARISON
SUMMARY OF COST OF GOVERNMENT FACILITIES
CASE C--1985

(Dollars in Thousands)

Site	Capital Cost	Rank	10-Year Operating Cost	Rank	Total 10-Year Cost	Rank	Annual Average Cost	Rank
1. Aguadilla	$230,420	5	$276,870	4	$507,290	4	$50,729	4
2. Añasco/Rincón	208,880	2	258,870	1	467,750	1	46,775	1
3. Punta Cabullon	211,870	3	259,460	2	471,330	2	47,133	2
4. Guayanilla	220,570	4	271,990	3	492,560	3	49,256	3
5. Jobos	231,890	6	286,550	5	518,440	5	51,844	5
6. Mona	207,620	1	354,190	6	561,810	6	56,181	6
7. Arecibo	381,720	7	400,590	7	782,310	7	78,231	7

TOTAL CAPITAL COST
ALL GOVERNMENT FACILITIES
CASE C--1985

(Dollars in Thousands)

	Aguadilla	Ãnasco/Rincón	Punta Cabullon	Guayanilla	Jobos	Mona	Arecibo
1. Petroleum terminal	$142,720	$122,480	$126,270	$142,720	$141,890	$135,870	$301,470
2. Petroleum industrial site	6,000	7,500	9,000	6,750	9,000	750	750
3. Support facilities	64,500	62,500	66,000	62,500	66,000	66,000	62,500
4. Distribution pipeline	14,200	13,400	7,600	5,600	12,000	-	14,000
5. Distribution barge terminals	3,000	3,000	3,000	3,000	3,000	5,000	3,000
Total	$230,420	$208,880	$211,870	$220,570	$231,890	$207,620	$381,720

CAPITAL COST OF PETROLEUM PORT AND TERMINAL FACILITIES
CASE C--1985

(Dollars in Thousands)

	Aguadilla	Añasco/Rincón	Punta Cabullon	Guayanilla	Jobos	Mona	Arecibo
1. Land acquisition							
a. Land	$ 2,000	$ 2,500	$ 3,500	$ 2,500	$ 3,500	$ 250	$ 800
b. Landfill	-	-	-	-	-	-	15,000
2. Dredging and navigational aids	1,000	500	500	3,600	500	2,500	136,500
3. Berths							
a. Crude import	39,000	24,000	24,000	30,000	24,000	39,000	30,000
b. Product	16,000	12,000	12,000	16,000	12,000	12,000	16,000
4. Trestle lines to shore	6,100	7,500	9,800	12,000	27,280	4,400	3,850
5. Tank farm and piping	52,000	52,000	52,000	52,000	52,000	52,000	52,000
6. Service craft	7,000	7,000	7,000	7,000	7,000	7,000	7,000
7. Service harbor and miscellaneous	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Subtotal	$124,100	$106,500	$109,800	$124,100	$123,380	$118,150	$262,150
8. Engineering and administration (15%)	18,620	15,980	16,470	18,620	18,510	17,720	39,320
Total	$142,720	$122,480	$126,270	$142,720	$141,890	$135,870	$301,470

CAPITAL COST OF PETROLEUM INDUSTRIAL SITE
CASE C--1985

(DOLLARS IN THOUSANDS)

	Aguadilla	Añasco/Rincón	Punta Cabullon	Guayanilla	Jobos	Mona	Arecibo
1. Land acquisition	$ 6,000	$ 7,500	$ 9,000	$ 6,750	$ 9,000	$ 750	$ 750
Subtotal--Land	$ 6,000	$ 7,500	$ 9,000	$ 6,750	$ 9,000	$ 750	$ 750
2. Support facilities							
a. Water supply	$ 6,000	$ 6,000	$10,000	$ 6,000	$10,000	$10,000	$ 6,000
b. Power plant	52,000	50,000	50,000	50,000	50,000	50,000	50,000
c. Waste treatment	4,000	4,000	2,500	4,000	3,500	3,500	4,000
d. Other	2,500	2,500	3,500	2,500	2,500	2,500	2,500
Subtotal--Support facilities	$64,500	$62,500	$66,000	$62,500	$66,000	$66,000	$62,500
Total	$70,500	$70,000	$75,000	$69,250	$75,000	$66,750	$63,250

10-YEAR OPERATING COST FOR PETROLEUM FACILITIES AND BARGE HIRE COSTS
CASE C--1985

(Dollars in Thousands)

	Aguadilla	Añasco/Rincón	Punta Cabullon	Guayanilla	Jobos	Mona	Arecibo
1. Interest cost							
a. Port and terminal	$ 47,570	$ 40,820	$ 42,090	$ 47,570	$ 47,290	$ 45,290	$100,480
b. Industrial site	2,000	2,500	3,000	2,250	3,000	250	2,500
c. Support facilities	21,500	20,830	22,000	20,830	22,000	22,000	20,830
d. Distribution	5,730	5,470	3,530	2,870	5,000	1,670	5,660
Subtotal-- Interest cost	$ 76,800	$ 69,620	$ 70,620	$ 73,520	$ 77,290	$ 69,210	$129,470
2. Operating cost							
a. Port and terminal							
. Labor	$ 44,800	$ 44,800	$ 48,800	$ 48,800	$ 52,800	$ 52,800	$ 40,800
. Consumables	11,200	11,200	12,200	12,200	13,200	13,200	10,200
b. Support facilities							
. Labor	4,750	4,750	5,200	5,250	5,750	5,700	4,250
. Consumables	14,250	14,250	15,580	15,750	17,250	17,300	12,750
c. Distribution							
. Labor	4,250	4,600	3,110	2,240	3,810	1,800	4,200
. Consumables	9,910	9,470	7,270	5,240	8,890	4,200	9,800
. Barge hire	16,160	16,160	10,720	16,480	10,720	98,960	16,160
Subtotal-- Operating cost	$105,320	$105,230	$102,880	$105,960	$112,420	$193,960	$ 98,160
3. Maintenance							
a. Port and terminal	$ 71,360	$ 61,240	$ 63,140	$ 71,360	$ 70,940	$ 67,940	$150,730
b. Industrial site	600	750	900	680	900	80	80
c. Support facilities	19,350	18,750	19,800	18,750	22,000	22,000	18,750
d. Distribution	3,440	3,280	2,120	1,720	3,000	1,000	3,400
Subtotal-- Maintenance	$ 94,750	$ 84,020	$ 85,960	$ 92,510	$ 96,840	$ 91,020	$172,960
Total	$276,870	$258,870	$259,460	$271,990	$286,550	$354,190	$400,590

8.0 SITE EVALUATION AND COMPARISON FOR PETROLEUM CASE D

8.1 Requirements and Specific Criteria

Case D superimposes a large export refinery on Case C. Requirements are given in Sections 3.1.5.2 and 3.1.5.3. Layouts are shown in Figures 38 through 49.

Case D is like Case C, with a higher level of crude oil imports and a much higher level of export products. For this to be accomplished, Case D facilities would thus include more VLCC berths for crude oil imports, more crude receiving tankage, greater refining capacity, more tankage for the accumulation of export products, and more product export tanker berths, together with their auxiliary installations. The requirements for tanker berths and total tank farm capacities are given in 3.1.5.2 and 3.1.5.3. The product volumes to be handled by the domestic distribution systems are the same as for Case C, and also for Case A, with the result that the tentative systems for comparing distribution costs are the same for all three of these cases.

8.2 Physical Comparison of Site Development and Distribution Systems

Due to the fact that Aguadilla could not physically accommodate the Case D level of exports, only six of the sites selected for the Case C comparisons were studied. Like the tentative development plans for Case C, those for Case D show the important components and industrial areas assigned at the respective sites. This being so, the information in the following sections will, for the most part, be limited to pointing out the differences between the two cases and the advantages and disadvantages from the physical standpoint.

8.2.1 Arecibo (Figures 38 and 39)

The ship basin would extend much further into the Caño Tiburones than for Case C. The bulk cargo, container-ship and dry cargo basin would be located further to the east. The same would be true of the petroleum industrial complex which would have the necessary larger land area than shown for Case C. Much more dredging and made land would be required, at great cost.

8.2.2 Jobos (Figures 40 and 41)

The petroleum industrial complex would be enlarged on land lying to the west of the area tentatively shown for Case C. The additional tanker berths would be larger versions of those for Case C.

8.2.3 Punta Cabullon (Figures 42 and 43)

The additional petroleum industrial area would be on land to the north of the Case C development. Possibly as shown, a portion or all of the metallurgical industrial area might be used for the additional petroleum facilities. The additional berth requirements could be satisfied with larger versions of the Case C installations.

8.2.4 Guayanilla (Figures 44 and 45)

Lack of suitable terrain would require the filling in of the Bahia de Guayanilla which lies north and north-northeast of the Punta Verraco peninsula. Dredge fill material could be obtained partly from the area shown for the additional product export berths and for tanker turning.

8.2.5 Añasco/Rincón (Figures 46 and 47)

Due to the limitation of suitable land, the Case D level of exports could be obtained only by eliminating the metallurgical industrial complex. Assuming no more land could be made available south of the Rio de Añasco, the full development of industrial facilities as well as the Case D refining and export level that is possible at most of the other sites might be attained by locating some of the refining capacity further to the north at one of the locations near Aguadilla where industrial installations would be possible. The refining facilities would be connected by pipelines to the petroleum terminal installations at Añasco.

8.2.6 Aguadilla

As mentioned under 8.2 above, Aguadilla would not be suitable for development to the Case D level. However, as discussed in 8.2.5, some of the refining facilities associated with a petroleum terminal at Añasco could be located on land near Aguadilla because of the practicability of moving crude oil and petroleum products by pipeline.

8.2.7 Isla Mona (Figures 48 and 49)

The additional land required for the larger petroleum industrial installations was assumed to be adjacent to the area shown on the Case C tentative development plan. The additional crude oil import berths would be more one-sided structures located close to the 120-foot depth contour. There would be more product export berths outside the dry cargo harbor breakwater.

8.3 Cost and Economic Impact Comparison

8.3.1 Cost Determination

The same procedures and unit prices used for the capital and operating costs of all the other cases of this study, which are explained in 5.3.1, were used for Case D.

The Case D capital costs and operating costs are those for facilities to be furnished by the government. As explained in 7.3.1 for Case C, all the industrial buildings, processing equipment and other plant requirements have been assumed to be planned, financed, constructed and operated by private companies.

The product distribution systems and their costs are the same as for Case C.

The Case D costs are based on coordinated planning and development of the ultimate capacity needed for 1985 volumes. Were planning and development for the Case C level undertaken to start with and then the program changed to attain the Case D levels, more total cost would be involved. For Arecibo, the tentative Case D development plan could not be implemented if work were far along or completed on the Case C facilities, as can be seen in Figures 24 and 48.

8.3.2 Cost Comparisons

There are five tables at the end of this Chapter 8 entitled:

- Site Comparison--Summary of Cost of Government Facilities
- Total Capital Cost--All Government Facilities
- Capital Cost of Petroleum Port and Terminal Facilities

- Capital Cost of Petroleum Industrial Site
- 10-Year Operating Cost for Petroleum Facilities and Barge Hire Costs

Each table contains the corresponding cost data for each site as per its tentative development plan for Case D, for ready comparison.

In the first table are the total capital and operating costs for the 10-year period of the study, from 1976 to 1985, that would be involved, equivalent to the total revenue required for each site.

The least cost would be for the Añasco/Rincón location, but this is only about 1.5% less than Punta Cabullon. Next in order of cost are Guayanilla, Jobos and Isla Mona. The latter is about 17% higher than Añasco/Rincón. Arecibo, because of the great dredging and landfill requirements, would be about 65% greater than Añasco/Rincón.

The reason for part of the difference between the Mona Island and Añasco/Rincón cost is that the product distribution distances for Mona are much greater than for any main island site and barge movement in privately owned and operated barges has been assumed in accordance with the criteria of 3.1.5.3, whereas for the main island sites distribution of all but the heavy fuels could be by government owned and operated pipelines.

If the barges were to be owned and operated by the government, the estimated barge haul costs for all sites would be approximately 16% less than those shown in the last table of this chapter. On this basis, the total 10-year cost for Isla Mona site would be reduced by about $15.4 million, but it would still rank sixth.

8.4 Demographic and Social Impact Comparison

This comparison would be essentially the same as given in 7.4 for the Case C comparison. For the increased export level, many more employees would be required than for Case C, and their wages would result in greater direct and indirect economic benefits to the area and to Puerto Rico. Involved also would be more housing and utilities to serve it.

8.5 Environmental and Ecological Factor Comparison

This comparison would be much like that of 7.5 for Case C. The major differences would be where additional dredging would be needed at some locations for the Case D level of exports. This would be true of Guayanilla and Arecibo.

8.6 Comparison of Flexibility of Future Use and Development

In this study, Case D's forecast requirements for 1985 are the highest volumes investigated. The only inkling of greater needs is in 3.1.5.1, where figures for new refining capacity in excess of present capacity, for the year 1990, are indicated. They show an increase in capacity from 3 million B/D in 1985 to 3.6 million in 1990. Exports are indicated at 2.7 million B/D in 1990, up from 2.35 million B/D in 1985. By proper planning and by limiting some of the non-petroleum industrial development, this moderate increase could be accommodated at any of the six Case D sites. Full industrial development of the Añasco/Rincón site with inclusion of the metallurgical industrial complex could only be accomplished by locating some of the petroleum industrial installations near Aguadilla as mentioned in 8.2.5. There would be good possibilities of locating those needed to achieve the 1990 forecast volumes by using more of the available land near Aguadilla. A still greater level might be possible by using more of the land near Aguadilla.

SITE COMPARISON
SUMMARY OF COST OF GOVERNMENT FACILITIES
CASE D--1985

(Dollars in Thousands)

Site	Capital Cost	Rank	10-Year Operating Cost	Rank	Total 10-Year Cost	Rank	Annual Average Cost	Rank
1. Aguadilla								
2. Añasco/Rincón	$381,430	1	$407,670	1	$ 789,100	1	$ 78,910	1
3. Punta Cabullon	391,070	2	411,400	2	802,470	2	80,247	2
4. Guayanilla	446,450	5	413,200	3	859,650	3	85,965	3
5. Jobos	435,670	4	457,570	4	893,240	4	89,324	4
6. Mona	414,570	3	512,310	5	926,880	5	92,688	5
7. Arecibo	663,160	6	638,560	6	1,301,720	6	130,172	6

TOTAL CAPITAL COST
ALL GOVERNMENT FACILITIES
CASE D--1985

(Dollars in Thousands)

	Aguadilla	Añasco/Rincón	Punta Cabullon	Guayanilla	Jobos	Mona	Arecibo
1. Petroleum terminal	-	$290,030	$296,470	$361,100	$336,670	$342,070	$582,160
2. Petroleum industrial site	-	12,500	18,000	14,250	18,000	1,500	1,500
3. Support facilities	-	62,500	66,000	62,500	66,000	66,000	62,500
4. Distribution pipeline	-	13,400	7,600	5,600	12,000	-	14,000
5. Distribution barge terminals	-	3,000	3,000	3,000	3,000	5,000	3,000
Total	-	$381,430	$391,070	$446,450	$435,670	$414,570	$663,160

CAPITAL COST OF PETROLEUM PORT AND TERMINAL FACILITIES
CASE D--1985

(Dollars in Thousands)

	Aguadilla	Añasco/Rincón	Punta Cabullon	Guayanilla	Jobos	Mona	Arecibo
1. Land acquisition							
a. Land	-	$ 2,500	$ 3,500	$ 2,500	$ 3,500	$ 250	$ 900
b. Landfill	-	-	-	-	-	-	15,000
2. Dredging and navigational aids	-	500	500	15,300	500	6,200	228,500
3. Berths							
a. Crude import	-	56,000	56,000	80,000	56,000	104,000	68,000
b. Product	-	42,000	42,000	56,000	42,000	42,000	48,000
4. Trestle lines to shore	-	15,000	19,600	24,000	54,560	8,800	9,625
5. Tank farm and piping	-	128,000	128,000	128,000	128,000	128,000	128,000
6. Service craft	-	7,000	7,000	7,000	7,000	7,000	7,000
7. Service harbor and miscellaneous	-	1,200	1,200	1,200	1,200	1,200	1,200
Subtotal	-	$252,200	$257,800	$314,000	$292,760	$297,450	$506,225
8. Engineering and administration (15%)	-	37,830	38,670	47,100	43,910	44,620	75,935
Total	-	$290,030	$296,470	$361,100	$336,670	$342,070	$582,160

CAPITAL COST OF PETROLEUM INDUSTRIAL SITE
CASE D--1985

(Dollars in Thousands)

	Aguadilla	Añasco/Rincón	Punta Cabullon	Guayanilla	Jobos	Mona	Arecibo
1. Land acquisition	-	$12,500	$18,000	$14,250	$18,000	$ 1,500	$ 1,500
Subtotal--Land	-	$12,500	$18,000	$14,250	$18,000	$ 1,500	$ 1,500
2. Support facilities							
a. Water supply	-	$ 6,000	$10,000	$ 6,000	$10,000	$10,000	$ 6,000
b. Power plant	-	50,000	50,000	50,000	50,000	50,000	50,000
c. Waste treatment	-	4,000	3,500	4,000	3,500	3,500	4,000
d. Other	-	2,500	2,500	2,500	2,500	2,500	2,500
Subtotal--Support facilities		$62,500	$66,000	$62,500	$66,000	$66,000	$62,500
Total	-	$75,000	$84,000	$76,750	$84,000	$67,500	$64,000

10-YEAR OPERATING COSTS FOR PETROLEUM FACILITIES AND BARGE HIRE COSTS
CASE D--1985

(Dollars in Thousands)

	Aguadilla	Añasco/Rincón	Punta Cabullon	Guayanilla	Jobos	Mona	Arecibo
1. Interest cost							
a. Port and terminal	-	$ 96,670	$ 98,810	$120,350	$112,210	$114,010	$194,030
b. Industrial site	-	4,170	6,000	4,750	6,000	500	500
c. Support facilities	-	20,830	22,000	20,830	22,000	22,000	20,830
d. Distribution	-	5,470	3,530	2,870	5,000	1,670	5,660
Subtotal-- Interest cost	-	$127,140	$130,340	$148,800	$145,210	$138,180	$221,020
2. Operating cost							
a. Port and terminal							
. Labor	-	$ 48,000	$ 51,200	$ 51,200	$ 56,000	$ 55,200	$ 43,200
. Consumables	-	12,000	12,800	12,800	14,000	13,800	10,800
b. Support facilities							
. Labor	-	5,500	6,000	6,000	6,500	6,500	5,000
. Consumables	-	16,500	18,000	18,000	19,500	19,500	15,000
c. Distribution							
. Labor	-	4,600	3,110	2,240	3,810	1,800	4,200
. Consumables	-	9,470	7,270	5,240	8,890	4,200	9,800
. Barge hire	-	16,160	10,720	16,480	10,720	98,960	16,160
Subtotal-- Operating cost	-	$112,230	$109,100	$111,960	$120,420	$199,960	$104,160
3. Maintenance							
a. Port and terminal	-	$145,020	$148,240	$130,550	$168,340	$171,040	$291,080
b. Industrial site	-	1,250	1,800	1,420	1,800	150	150
c. Support facilities	-	18,750	19,800	18,750	19,800	1,980	18,750
d. Distribution	-	3,280	2,120	1,720	3,000	1,000	3,900
Subtotal-- Maintenance	-	$168,300	$171,960	$152,440	$192,940	$174,170	$313,380
Total	-	$407,670	$411,400	$413,200	$457,570	$512,310	$638,560

9.0 RATING AND SELECTION OF MOST FAVORABLE SITES FOR EACH PETROLEUM CASE AND COMPARISON FACTORS

9.1 Cost and Economic Impact

Most important in site screening is a comparative evaluation of the cost and economic impact of each site. It has been assumed that all sites will yield similar overall economic benefits for the same level of development. Therefore, no effort has been expended on cost benefit analysis in this study. Such an analysis would have greatest value in comparing the development cases themselves.

Capital and operating costs, including debt service, were determined as explained in 5.3, 6.3, 7.3 and 8.3, for Cases A, B, C and D respectively. A summary comparison of 10 year site costs for Cases A, B, C and D is contained in Table 9A near the end of this chapter. This comparison makes it possible to determine, for each case and each site, the total estimated capital investment required by the government of Puerto Rico. The summary comparison figures are 1973 dollars and include the approximate total operating cost for the assumed 10-year study period, together with interest on borrowed funds and costs for hiring privately owned barges for crude or product distribution.

The total of capital cost plus the operating costs for 10 years would approximate the total revenue required by the government to "break even" in the 10-year period. It is assumed that revenue will cover all obligations such as loan amortization and interest, but with no build-up of a depreciation reserve, or any profit. This simple method of comparison is adequate for this stage of site screening and is easier to appraise than more sophisticated methods. In final screening, more emphasis would be placed on capital costs and, in particular, initial investment.

Care should be taken when attempting to compare costs of alternate sites or different cases. The costs for different cases are not completely comparable in all respects.

Case A

For Case A, the cheapest method for importing products is to deliver them directly to the consuming centers. This is the multiple terminal case. While this apparently requires higher capital investment for terminal facilities, there are compensating savings in operating and distribution costs. There may also be capital savings if the new facility requirements can be incorporated in existing installations.

If the multiple terminal solution is not acceptable, a central terminal at either Punta Cabullon or Guayanilla would be least expensive. Given the inherent accuracy of a site screening study cost estimate, there is little to choose between them, but Punta Cabullon does appear slightly cheaper.

Following the first two in cost ranking are developments at either Añasco or Aguadilla and then Jobos, in that order. Neither Mona nor Arecibo would be economically feasible for Case A.

Case B

For Case B, importing crude oil to existing refineries through a central terminal at either Guayanilla or Punta Cabullon would be least expensive. This would be followed by either Jobos or Añasco and then Aguadilla. Neither Mona nor Arecibo would be economically attractive for this case as analyzed.

Note, however, that the capital investment for terminal facilities at Mona would not in itself be excessive. The main reason for the higher cost at Mona is the operating cost of barges for transporting the crude to main island refineries. If the barge costs could be reduced, or somehow subsidized, Mona could be considered feasible for this purpose.

Case C

For Case C, with a refinery to serve primarily Puerto Rico, the least expensive site would be Añasco, followed closely by Punta Cabullon and then Guayanilla, Aguadilla and Jobos. Arecibo would not be economically feasible. Development at Isla Mona appears expensive, but, as with Case B, this is primarily because of distribution costs for internal products. On a capital basis and for export operations, Mona is among the least expensive sites. Further study may reveal means for reducing distribution costs and making Mona more attractive.

Case D

For Case D, with a large export refinery, Añasco again appears the least expensive, followed closely by Punta Cabullon and then Guayanilla, Jobos and Mona. The site at Arecibo is still not economically feasible. The site at Aguadilla is no longer suitable because of its limited land area and water front.

It should be noted that again, the main reason for higher cost at Mona is the internal distribution cost. The terminal and site facilities at Mona are more expensive than those at Añasco or Punta Cabullon, but cheaper than the other sites.

In summary, Punta Cabullon, ranking first or second on the basis of cost for any of the development cases considered, must be considered a leading site. Also among the leaders on the basis of cost are Añasco and Guayanilla.

If Cases C and D are given more importance than A or B, then Añasco becomes the more favored site. This is a reasonable weighting, since the larger development cases are expected to result in greater economic benefits. Also, it is probable that neither Case A nor Case B will be fully accepted on the basis of environmental impact.

Considering Case C and especially Case D, cost and economic impact screening result in the following ranking:

1. Añasco
2. Punta Cabullon
3. Guayanilla
4. Jobos
5. Aguadilla or Isla Mona

9.2 Demographic and Social Impact

In considering social impact, it is apparent that there should be two separate categories of sites. The sites on the main island of Puerto Rico can be compared on a similar basis, but the social impact of development of uninhabited Isla Mona is in a class by itself.

Of the main island sites, Punta Cabullon and Jobos would require the least amount of people to relocate. Añasco, along with Guayanilla has slightly more people. At Aguadilla there are many homes, some of which are new, that would have to be destroyed.

Isla Mona would require no destruction of existing homes. On the contrary, it would present an opportunity for high grade urbanization of an otherwise uninhabitable tract of land. This is of major significance in densely populated Puerto Rico. In addition, since all of the population on Mona would be earning a living, directly or indirectly, from the installations there, less social objection should be expected from the local populace.

Isla Mona is far enough from the main island to be over the horizon and not visible. Industrial installations and tanker traffic would thus be out of sight of the main populace. At all other sites still in consideration such activity would be highly visible and could be considered intrusive.

At all of the sites, except Aguadilla and Mona, the undeveloped land is considered good agricultural land. At Aguadilla it is mostly poor. The land on Isla Mona is unsuitable for agriculture.

Since all main island sites are fifteen year tax exemption zones, their impact on local unemployment is probably about equal. All sites have inadequate social services that must be increased for the project. This is either a benefit or an adverse factor depending on the point of view. Weighing all factors together, all main island sites appear about equal in social impact, with Aguadilla rated somewhat behind the others because of the number of homes to be destroyed and the possible adverse affect on nearby recreational beaches.

Isla Mona, on the other hand, appears far ahead of the main island sites in having greatest potential social benefits with least adverse effects. The beneficial economic effects of development of Mona on increased employment in the west coast area of Puerto Rico should be almost as much as if the development was carried out there. At the same time, there would be no need to take the large tracts of land out of other use as would be the case with a west coast development.

This, combined with the greatest potential for improved living standards and social services for the Mona workers, should make Mona the most desirable site for major development of heavy industry in Puerto Rico.

9.3 Environmental and Ecological Factors

Other investigators have been making a detailed analysis of these factors. Based on their preliminary findings and known data, an approximate comparison can be made. These factors are considered decisive enough by some environmentalists and ecologists to overturn the economic ranking of the sites in some cases.

Based on the expressed opinion of the Fomento Environmental Study Team and other government agencies and special consultants, all south coast sites should be eliminated from consideration for either further petroleum port development or petroleum industrial development. The reason given for port development is the danger of damage from oil spills; for industrial development, the danger of further air pollution from stack emissions. This would be true equally of Punta Cabullon, Guayanilla and Jobos. Nonetheless, because of its other advantages, we believe Punta Cabullon should be considered further. Jobos and Guayanilla however, each with fewer advantages, can probably be eliminated on this basis.

The environmental study team has cited strong opposition of local environmentalists and conservationists to use Isla Mona as a deep-water port or refinery. While it is acknowledged that development on Mona would have little or no environmental impact on the main island, there is concern over the ecology of Mona itself. There is concern on the part of government officials charged with wild life preservation and environmental protection over rare and endangered species. However, the team listed many features, which if incorporated, would reduce the environmental impact of the installation and actually protect wild life. They also recommend obtaining additional detailed observations and measurements in order to more accurately assess the effects on the site. Of great interest are certain species of flora, several very rare, and found only on Mona. Also there is a special species of iguana. Certainly, in any development on Mona, great care should be taken to identify rare flora as well as fauna, and to ensure their propagation. If a decision was made to develop Mona, it should be possible to work out a plan that--even though an installation would have a severe impact on portions of the island--would protect a major portion of the land area and limit shoreline damage. This would be a plan developed by all concerned parties.

The environmental study team reports that Aguadilla is the best site for the deep-water port and refinery location, from a purely environmental standpoint, although they recognize that nearby land available for industrial development is limited. Major reasons are an almost complete lack of valuable marine life and limited reversal of normal trade winds to the onshore direction.

In the Añasco/Rincón area the team found no ecological reasons against the deep-water port and associated industries, but pointed out that there are calms or light onshore winds for a significant portion of the year. This could be undesirable from an air pollution standpoint, although there is some evidence that this is only at a low level and that a high stack could penetrate to a trade wind zone.

Punta Cabullon was also given a good ecological rating by the team, but they did not report on air pollution possibilities from onshore winds. It is obvious from its location that the city of Ponce would suffer from air pollution at this site. In view of the negative position regarding south coast sites previously described, Punta Cabullon could be eliminated or put in a less favorable position.

In summary, development on Isla Mona would present minimum environmental impact on the main island populace, but was found to present a danger to wild life ecology. Other sites to be considered are Añasco, Aguadilla and possibly Punta Cabullon as an alternate.

9.4 Potential Development for Non-Petroleum Use

For the various cases studied, based on a low total cost, Punta Cabullon offers the greatest flexibility. A possible exception is for the metallurgical industrial development which will probably have to be omitted because of air pollution and proximity to Ponce. It would be ideal for a container-ship port, dry bulk handling or general cargo port, as well as for a shipyard. These would be possible even if a deep-water petroleum port were not part of the development. Dredging would be required to obtain sufficient water depth and land fill (Figures 28 to 42).

Añasco has less shore frontage than Punta Cabullon but has adequate nearby land areas. A metallurgical plant would cause air pollution during the season of prevailing onshore winds. Other than that, facilities for container ships and general cargo vessels, as well as bulk cargo ships, could be provided as shown on the tentative development plans for Cases C and D (Figures 32 and 46). Dredging in hard bottom material would be required. It would present an excellent site for a shipyard if petroleum facilities were not developed on a large scale.

Isla Mona has sufficient room for a metallurgical industrial development, and is an especially desirable site for this because of the great dispersion and dilution of air pollution over the open sea. It would be suitable for any other industries whose products, whether for export or for main island use, could be transported and priced competitively. There is ample space to provide any facilities required to bring in and to ship out containers, as well as to handle dry bulk and general cargos.

Aguadilla is extremely limited for other use if a major petroleum installation was developed. On the other hand, it well could be developed for a steel mill or other metallurgical plant. Because of wind and ecological conditions, the site at Punta Borinquen may be the only acceptable site for a high emission metallurgical plant on the main island.

9.5 Flexibility for Future Use and Development

With the exception of potential air pollution drifting over the city of Ponce, Punta Cabullon is the most flexible main island site examined. While it might be possible to keep pollution caused by a moderate sized refinery within acceptable limits, it cannot be done for a metallurgical industrial development or, possibly a large refinery. Hence these types of industry might have to be excluded. For suitable types of installations, the extent of available land, the even shore line and the expanse of protected water area with suitable bottom conditions makes it desirable because of its flexibility. For example, it could be undertaken for Case B or C levels and changed later to the Case D development with little difficulty, if within tolerable air pollution levels.

At Añasco/Rincón there is also a potential air pollution problem due to the onshore winds which prevail for a significant portion of each year. Since the fumes and vapors from a major industrial development might exceed acceptable limits, this could limit development in the Añasco/Rincón area. Otherwise there is considerable flexibility of future development.

At Aguadilla the wind reversals to onshore occur infrequently and only when trade winds are light. This would indicate no restrictions from air pollution. On the other hand, land and shore frontage are limited and a large development is not suited.

The Isla Mona site's flexibility is limited only by the need to orient and locate the VLCC berthing structures along the 120 foot contour, the need to use as little shoreline as possible and to preserve and protect a wild life conservation area. It is practically unlimited in expansion possibilities. Mona is least suited for a small installation. This is its main drawback, with this lack of flexibility, it cannot realistically be started small and then be expanded conservatively.

Table 9A

SUMMARY COMPARISON OF 10-YEAR SITE COSTS FOR GOVERNMENT FACILITIES FOR CASES A, B, C and D FOR 1985 VOLUME LEVELS

(Dollars in Thousands)

Case	Site	Capital Cost	Rank	10-Year Operating Cost	Rank	Total 10-Year Cost	Rank	Average Annual Cost	Rank
A	Multi-terminals	$ 69,300		$ 67,740		$ 137,040		$ 13,704	
	Central terminal at:								
	. Aguadilla	63,780	4	111,910	4	175,690	4	17,569	4
	. Añasco/Rincón	63,550	3	111,800	3	175,350	3	17,535	3
	. Punta Cabullon	57,690	1	102,590	1	160,280	1	16,028	1
	. Guayanilla	58,230	2	106,510	2	164,740	2	16,470	2
	. Jobos	71,270	5	116,080	5	187,350	5	18,735	5
	. Mona	-							
	. Arecibo	-							
B	. Aguadilla	162,929	6	225,800	5	388,729	5	38,873	5
	. Añasco/Rincón	148,700	5	213,010	3	361,710	4	36,171	4
	. Punta Cabullon	130,355	1	192,740	2	323,095	2	32,310	2
	. Guayanilla	131,000	2	190,260	1	321,260	1	32,126	1
	. Jobos	143,860	4	216,400	4	360,260	3	36,026	3
	. Mona	143,240	3	580,140	7	723,380	7	72,338	7
	. Arecibo	315,370	7	344,860	6	660,230	6	66,023	6
C	. Aguadilla	230,420	5	276,870	4	507,290	4	50,729	4
	. Añasco/Rincón	208,880	2	258,870	1	467,750	1	46,775	1
	. Punta Cabullon	211,870	3	259,460	2	471,330	2	47,133	2
	. Guayanilla	220,570	4	271,990	3	492,560	3	49,256	3
	. Jobos	231,890	6	286,550	5	518,440	5	51,844	5
	. Mona	207,620	1	354,190	6	561,810	6	56,181	6
	. Arecibo	381,720	7	400,590	7	782,310	7	78,231	7
D	. Aguadilla	-	-	-	-	-	-	-	-
	. Añasco/Rincón	381,430	1	407,670	1	789,100	1	78,910	1
	. Punta Cabullon	391,070	2	411,400	2	802,470	2	80,247	2
	. Guayanilla	446,450	5	413,200	3	859,650	3	85,965	3
	. Jobos	435,670	4	457,570	4	893,240	4	89,324	4
	. Mona	414,570	3	512,310	5	926,880	5	92,688	5
	. Arecibo	663,160	6	638,560	6	1,301,720	6	130,172	6

10.0 RECOMMENDATION FOR SITE SELECTION AND DEVELOPMENT

10.1 Selection

The following discussion on preferred and alternate sites for each case was developed from the comparison information in Chapter 9.0.

Case A - The preferred site is Punta Cabullon. It is the lowest in cost and since importation and distribution of products would be its only activity, air pollution would be essentially non-existent. With proper oil spill precautions and procedures, damage would be minimal. The alternate site for Case A is Añasco/Rincón. Even though this site would involve a slightly greater total cost than Guayanilla, it is decidedly better from an ecological standpoint. It would be the preferred site if all south coast sites were excluded from consideration.

Case B - The preferred site is Punta Cabullon. Since importation and distribution of products will be the only activity, air pollution would be non-existent. Proper oil spill precautions and recovery procedures would be required, as mentioned in Case A. Guayanilla or Jobos would be alternates. If all south coast sites were excluded, Añasco/Rincón would be the preferred location.

Case C - The preferred main island site development is a combination of the Añasco/Rincón and Aguadilla sites. Further study would be needed to determine the best development. To essentially eliminate air pollution, any metallurgical complex should be near Aguadilla because the onshore wind problem is minimal as compared to Añasco. This would require the bulk unloading facilities to be at Aguadilla. The crude unloading and product export terminal, and some refining capacity, would be at and near Añasco. It would also be desirable to have some refining capacity near Aguadilla, which can be supplied with crude by pipeline from the Añasco terminal. Returning export products to the Añasco terminal can also be transferred by pipeline. The refining installation should be built near the metallurgical facilities so that residual fuel could be supplied by short pipeline connections. Potential air pollution from any power generating plant would be less with the plant located near Aguadilla where it also could be supplied directly from the Aguadilla refining installation.

The best alternate site for Case C is Isla Mona, its major drawback is its isolation and higher cost of product distribution because of the tug-barge units required for this service. The cost of hauling from Mona to the main island warrants further investigation. There are good prospects of reducing barging costs considerably for, in this screening study, a very conservative equipment estimate, costing method and barge operating and scheduling method was used. An obvious way to reduce total 10 year costs for Mona would be the use of government-owned and operated barges. To date, no submarine pipelines have been laid in water as deep as that between Mona and the main island, although many equally long have been installed. The possibility of pipeline transport to the main island should be investigated, taking into consideration the latest technical and construction advances in this field.

Another feature that could possibly augment the desirability of Mona would be the construction of a substantial thermo-electric plant, which could supply some of the growing power requirements on the main island via a submarine cable connection. The practicability of doing this is discussed in Appendix I. Using high sulphur residual fuel from the Mona refining complex should pose no pollution problem due to the great downwind dilution of stack gases over the open sea. For a main island power installation at almost any site, low sulphur fuel would be required. If the source was the Mona refinery, this fuel would have to be moved to the main island. An investigation of the economics of the submarine cable scheme is warranted.

Case D - For the reasons set forth under Case C above, the preferred main island site development would be a combination of the Añasco/Rincón and Aguadilla sites, with components of the development tentatively divided between these locations in the same manner. Further study to optimize planning would be needed. There is some question about the acceptability of such a development at these sites.

The best alternate, and probably preferred site, would be Isla Mona. The comments under Case C regarding the possibilities of reducing barge hauling costs and the economics of supplying power to the main island via submarine cable, apply to Case D, and these matters should be investigated as described under Case C.

10.2 Implementation Procedure

As soon as a decision is reached by the appropriate Puerto Rico governmental authority to develop a deep-water port and terminal at a selected site, many important steps will have to be taken before actual construction can get underway. Some, but not all, of these are:

a. Determining what permits will be needed, obtain application forms and information on the requirements for successful preparation of all applications. This will involve a great deal of careful work so that an assessment of environmental impacts may be made. Public hearings will be held. Careful preparation of exhibits and other material for making presentations and answering questions at these hearings will be required. Completion of some of the following steps will be necessary in connection with the permit work.

b. Conduct thorough field investigations for the ecosystems at the selected site and the best alternate sites.

c. Survey and investigate work such as detailed soundings, underwater borings, wind and wave patterns, onshore soil testing and information on all inhabitants and dwellings to be relocated. This should be done in great detail at the selected site, for use in final design. At the alternate sites, if any, the work should be adequate to fulfill all the requirements for a complete environmental impact statement.

d. Make a complete preliminary design for the initial development to be undertaken, and for subsequent installations to handle estimated growth in throughput. These must be sufficiently complete so they may be used to prepare reliable budget estimates. Variations in designs required at the alternate sites should be determined so differences in cost for an equivalent development may be estimated.

e. Make comparative economic studies to optimize the financial requirements and to determine the best schedules for fundings and debt repayment. These studies will reveal the required tariffs necessary to cover the various operational costs, such as: unloading crude and delivering it to the refineries, receiving export products and loading them aboard tankers, receiving products for domestic use and delivering them to the consuming centers.

f. Complete designs, plans and specifications for construction and mobile equipment. Timing on this will depend on the progress in obtaining the permits, obtaining commitments for use of the facilities and obtaining funds for performing this work.

g. Following completion of all financial arrangements, bids would be invited and contractual arrangements made for carrying out the various phases of the work. Construction work would follow, with supervision and inspection by representatives of the owner.

11.0 RECOMMENDED PROGRAMS

To implement the development of a deep-water petroleum port and terminal at one of the sites, an existing government organization may be designated to have responsibility for the project, or a new government authority may be established to administer all aspects of the project throughout its life. The latter is the recommended action. Ultimate authority in the organization would be a board of directors. It would be provided with sufficient organizational funds and be empowered to issue tax-free securities to fund its development activities.

Some of the important initial steps required are described in 10.2. These tasks would be performed or supervised by an engineering organization. To expedite matters, some of the preliminary work of 10.2 might be performed under the auspices of an existing government organization such as the Economic Development Administration with liaison through the Puerto Rico Industrial Development Company. Then, when the new authority has been organized, administration of this work would be transferred to it.

Key tasks facing the new authority would be:

a. Develop master plan for organization based on a tentative project schedule.

b. Arrange for financing activities through the planning stages.

c. Administer the work described in 10.2.

d. Acquire necessary land and pipeline rights of way, and arrange to relocate inhabitants where necessary.

e. Arrange contracts, monetary guarantees, and other commitments with users, including standards for users' receipt and delivery equipment or installations and policies and procedures for custody transfer.

f. Supervise development of and letting construction contracts.

g. Arrange for acquisition of all mobile and other equipment and initial supplies required to start operations.

h. Establish and supervise the project operating organization.

i. Operate the owned facilities, collect tariffs, pay all expenses and repay borrowed funds, adjusting tariffs as necessary for zero profit.

Any decision to proceed with the deep-water port project would no doubt also include the type or level of development, that is whether it would like Case A, B, C or D of this study or some variation of one of these.

The financing basis assumed for this study seems logical. Thus the new authority would construct, own and operate the following:

Terminal berths, tank farms and transfer systems to users' tanks.

Harbor and service craft

Other possible port facilities

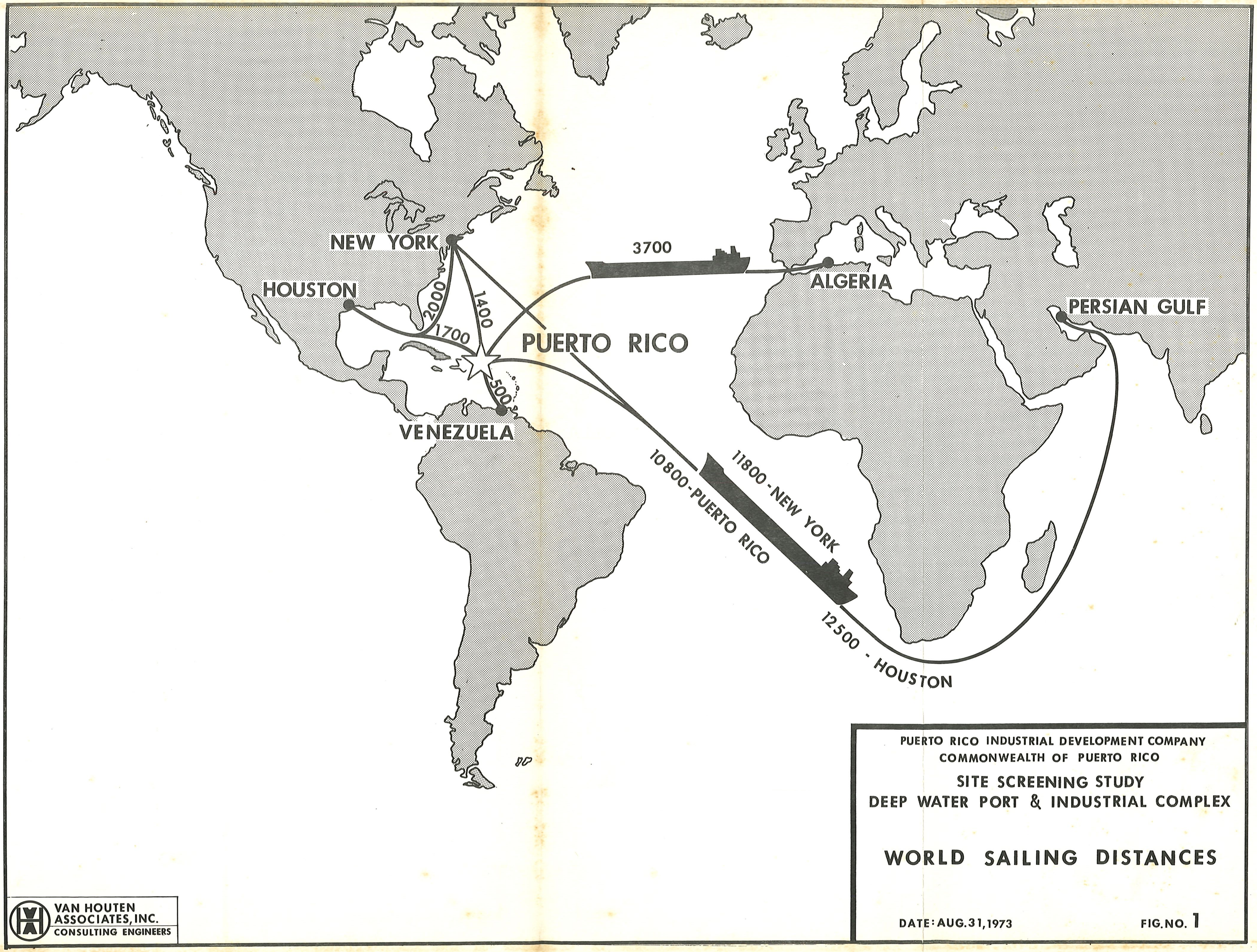
Ancillary support facilities and services, such as:

- Water supply system
- Waste treatment and disposal systems
- Service roads for common usage
- Land for refinery installations and other industrial plants
- Distribution pipelines
- Distribution barge terminals

Additional power requirements could be supplied by new plants constructed and operated by the new authority. However, it would be preferable if the Puerto Rico Water Resources Authority undertook this work.

For simplicity throughout this study it has been assumed, for costing purposes, that all facilities sufficient to handle 1985 estimated throughput would be built at the very beginning. In the final planning for construction and financing, the ultimate development should be broken down into three construction stages, about three years apart. This assumes that final planning calls for an initial 10-year period throughput growth followed by a period of no growth.

Should Isla Mona be selected as the site, consideration should be given to means for obtaining lower barge haul costs. This could be done by using government owned barges or a different barge scheduling method, or both. The feasibility of submarine pipelines between Mona and the main island should be investigated, as should the economics of a large power capacity on Mona serving the main island via submarine cable.



PUERTO RICO INDUSTRIAL DEVELOPMENT COMPANY
COMMONWEALTH OF PUERTO RICO

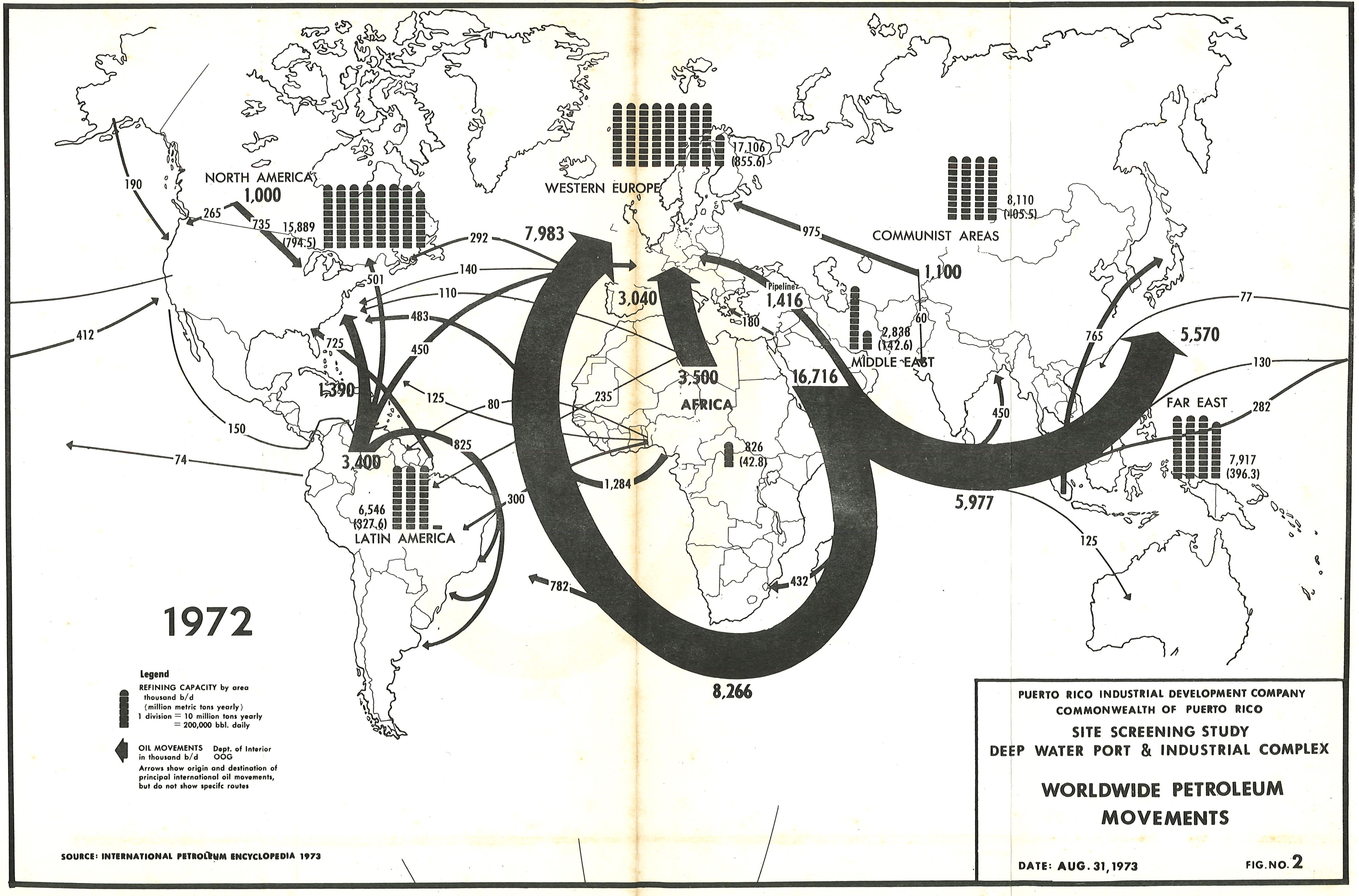
SITE SCREENING STUDY
DEEP WATER PORT & INDUSTRIAL COMPLEX

WORLD SAILING DISTANCES

DATE: AUG. 31, 1973

FIG. NO. 1

VAN HOUTEN
ASSOCIATES, INC.
CONSULTING ENGINEERS



SOURCE: INTERNATIONAL PETROLEUM ENCYCLOPEDIA 1973

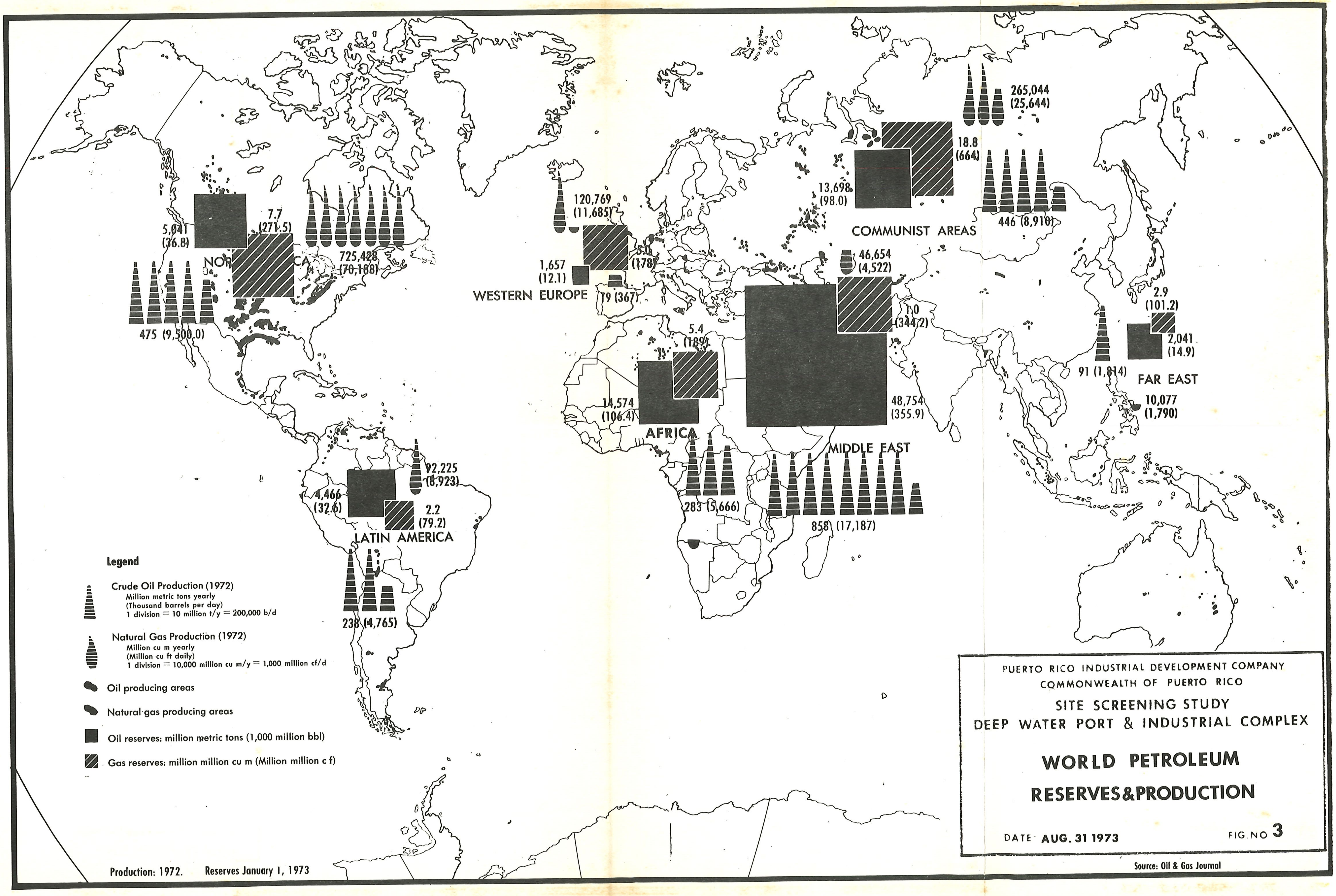
PUERTO RICO INDUSTRIAL DEVELOPMENT COMPANY
COMMONWEALTH OF PUERTO RICO

SITE SCREENING STUDY
DEEP WATER PORT & INDUSTRIAL COMPLEX

WORLDWIDE PETROLEUM MOVEMENTS

DATE: AUG. 31, 1973

FIG. NO. 2



PUERTO RICO INDUSTRIAL DEVELOPMENT COMPANY
COMMONWEALTH OF PUERTO RICO

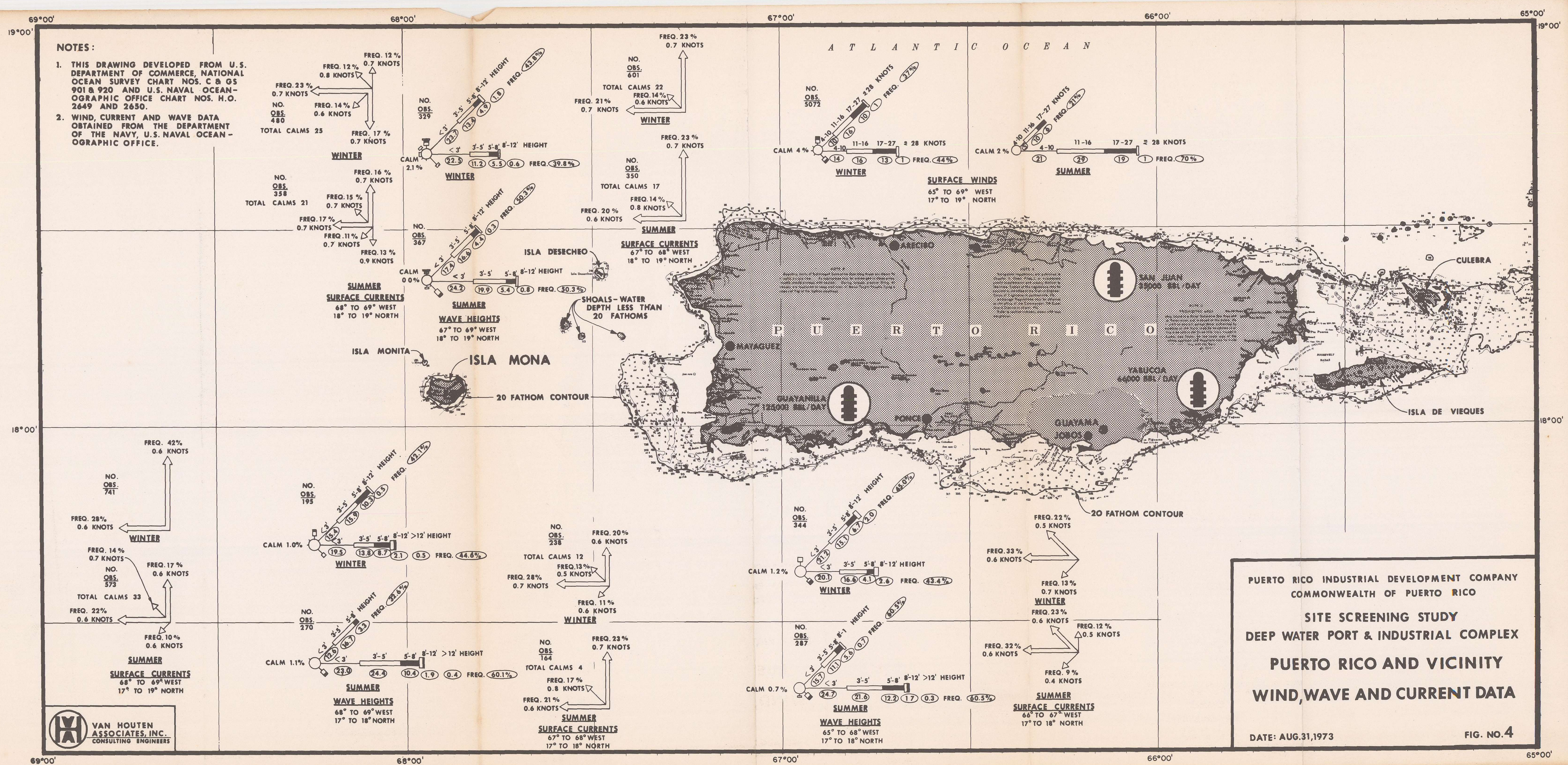
SITE SCREENING STUDY
DEEP WATER PORT & INDUSTRIAL COMPLEX

WORLD PETROLEUM
RESERVES&PRODUCTION

DATE AUG. 31 1973

FIG. NO 3

Source: Oil & Gas Journal



NOTES :

1. THIS DRAWING DEVELOPED FROM U.S. DEPARTMENT OF COMMERCE, NATIONAL OCEAN SURVEY CHART NOS. C & GS 901 & 920 AND U.S. NAVAL OCEANOGRAPHIC OFFICE CHART NOS. H.O. 2649 AND 2650.
2. WIND, CURRENT AND WAVE DATA OBTAINED FROM THE DEPARTMENT OF THE NAVY, U.S. NAVAL OCEANOGRAPHIC OFFICE.

PUERTO RICO INDUSTRIAL DEVELOPMENT COMPANY
COMMONWEALTH OF PUERTO RICO

SITE SCREENING STUDY
DEEP WATER PORT & INDUSTRIAL COMPLEX

PUERTO RICO AND VICINITY
WIND, WAVE AND CURRENT DATA

DATE: AUG.31,1973

FIG. NO.4

VAN HOUTEN
ASSOCIATES, INC.
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PUERTO RICO INDUSTRIAL DEVELOPMENT COMPANY
COMMONWEALTH OF PUERTO RICO

SITE SCREENING STUDY
DEEP WATER PORT & INDUSTRIAL COMPLEX

ROAD MAP - PUERTO RICO

DATE: AUG.31, 1973 FIG.NO. 5

ESTADO LIBRE ASOCIADO
DEPARTAMENTO DE TRANSPORTACION Y OBRAS PUBLICAS
AUTORIDAD DE CARRETERAS

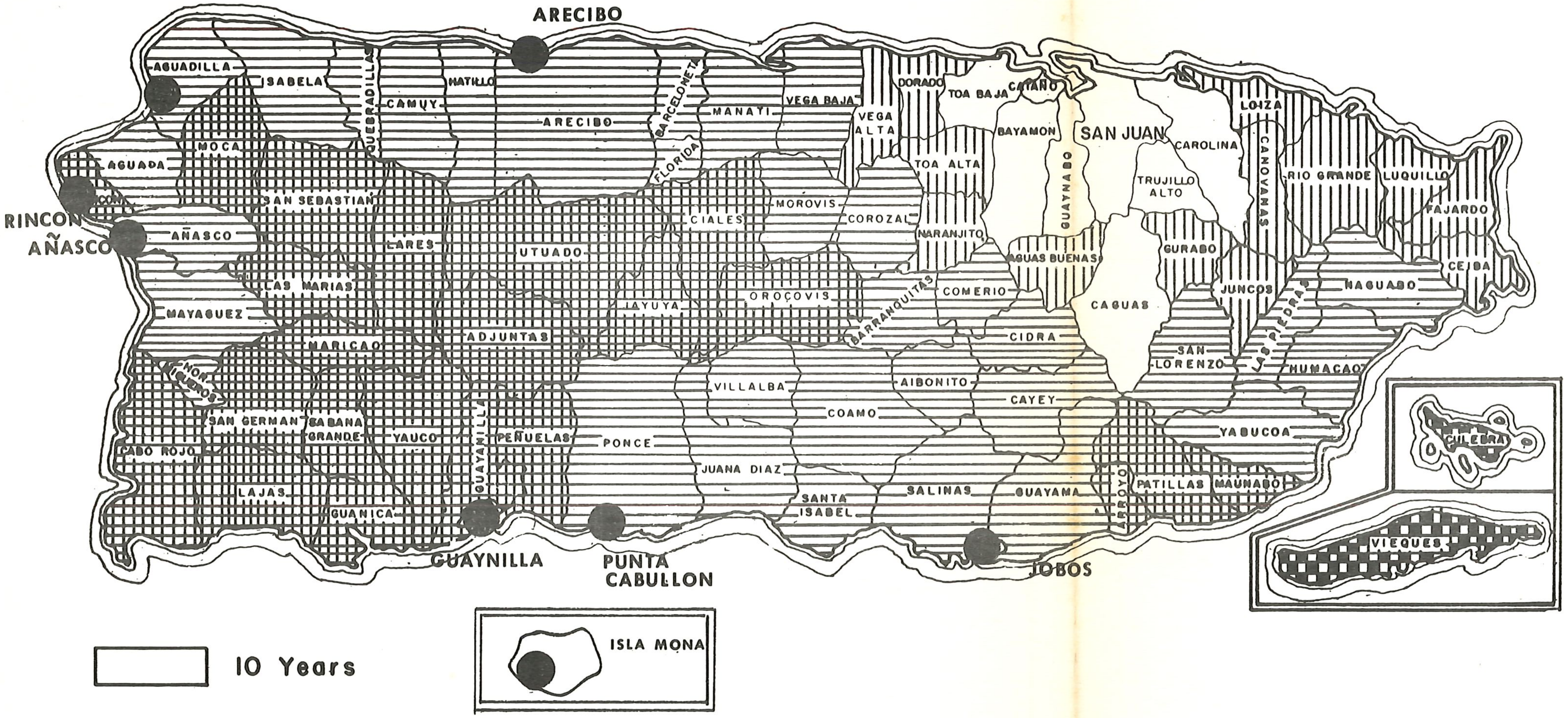
MAPA DE CARRETERAS ESTATALES DE PUERTO RICO

AL 31 DE ENERO DE 1973

Dennis W. Hernandez
DENNIS W. HERNANDEZ
SECRETARIO
DEPARTAMENTO DE TRANSPORTACION Y OBRAS PUBLICAS

HAMILTON RAMIREZ
DIRECTOR EJECUTIVO INTERINO
AUTORIDAD DE CARRETERAS

PUERTO RICO
INDUSTRIAL TAX EXEMPTION ZONES
1972



☐ 10 Years

▥ 12 Years

▤ 15 Years

▦ 17 Years

▩ 25 Years

(In accordance with Administrative Bulletin No. 1510 and No. 1808 and Act. No. 19 approved, June 15, 1972)

Economic Development Administration
Office of Economics and Planning

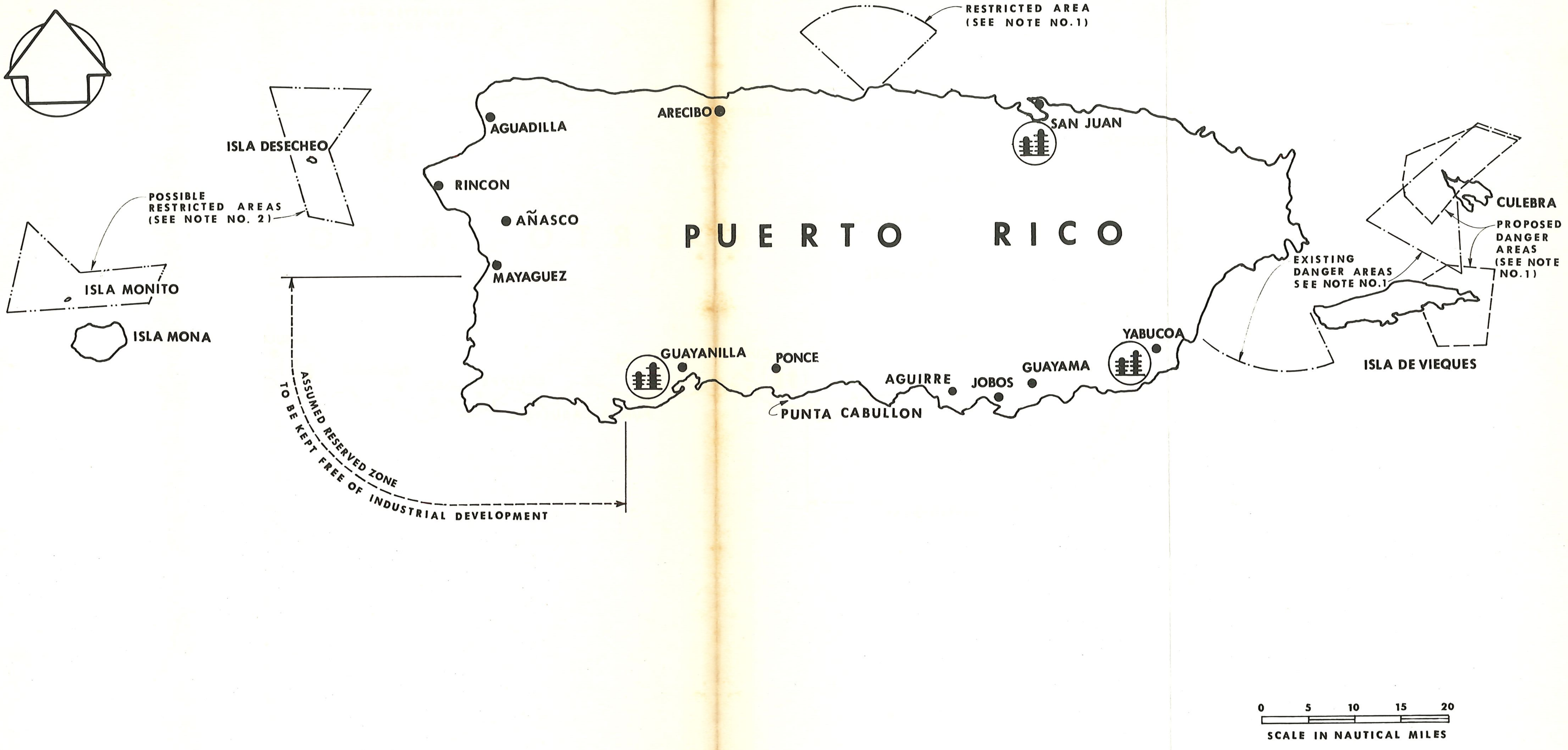
PUERTO RICO INDUSTRIAL DEVELOPMENT COMPANY
COMMONWEALTH OF PUERTO RICO

SITE SCREENING STUDY
DEEP WATER PORT & INDUSTRIAL COMPLEX

INDUSTRIAL TAX EXEMPTION ZONES

DATE: AUG.31, 1973

FIG.NO. 6


RESTRICTED AREA (SEE NOTE NO.1)
ISLA DESECHEO
POSSIBLE RESTRICTED AREAS (SEE NOTE NO. 2)
ISLA MONITO
ISLA MONA
AGUADILLA
ARECIBO
SAN JUAN
RINCON
AÑASCO
MAYAGUEZ
PUERTO RICO
CULEBRA
PROPOSED DANGER AREAS (SEE NOTE NO.1)
EXISTING DANGER AREAS SEE NOTE NO.1
YABUCOA
GUAYANILLA
PONCE
AGUIRRE
JOBOS
GUAYAMA
PUNTA CABULLON
ISLA DE VIEQUES
ASSUMED RESERVED ZONE TO BE KEPT FREE OF INDUSTRIAL DEVELOPMENT
0
5
10
15
20
SCALE IN NAUTICAL MILES

NOTES

1. DANGER AREAS ARE FROM CHART NO. C &GS 920, DATED MARCH 1973. PROPOSED DANGER AREAS ARE FROM U.S. CORPS OF ENGINEERS NOTICE DOD-314 DATED 5 JUNE 1973.
2. POSSIBLE RESTRICTED AREAS BASE ON EXISTING DANGER AREAS AT CULEBRA.

VAN HOUTEN ASSOCIATES, INC.
CONSULTING ENGINEERS, NEW YORK

PUERTO RICO INDUSTRIAL DEVELOPMENT COMPANY
COMMONWEALTH OF PUERTO RICO

SITE SCREENING STUDY
DEEP WATER PORT & INDUSTRIAL COMPLEX

DANGER & RESTRICTED AREAS

DATE: AUG. 31, 1973

FIG. NO. 7

VAN HOUTEN ASSOCIATES, INC.
CONSULTING ENGINEERS, NEW YORK

LEGEND

△	NUMBER OF EXISTING PETROCHEMICAL PLANTS (1972)
▣	POSSIBLE INDUSTRIAL SITE
○	POSSIBLE DEEP WATER SITE
⊕	EXISTING REFINERIES (1972)

NOTES:

1. THIS DRAWING DEVELOPED FROM UNITED STATES DEPARTMENT OF INTERIOR; GEOLOGICAL SURVEY CHART OF PUERTO RICO AND ADJACENT ISLANDS, 1951.
2. LAND CONTOURS INTERVALS ARE IN 50 METER INCREMENTS.

SCALE IN KILOMETERS
10 5 0 5 10 15 20
5 0 5 10
SCALE IN MILES

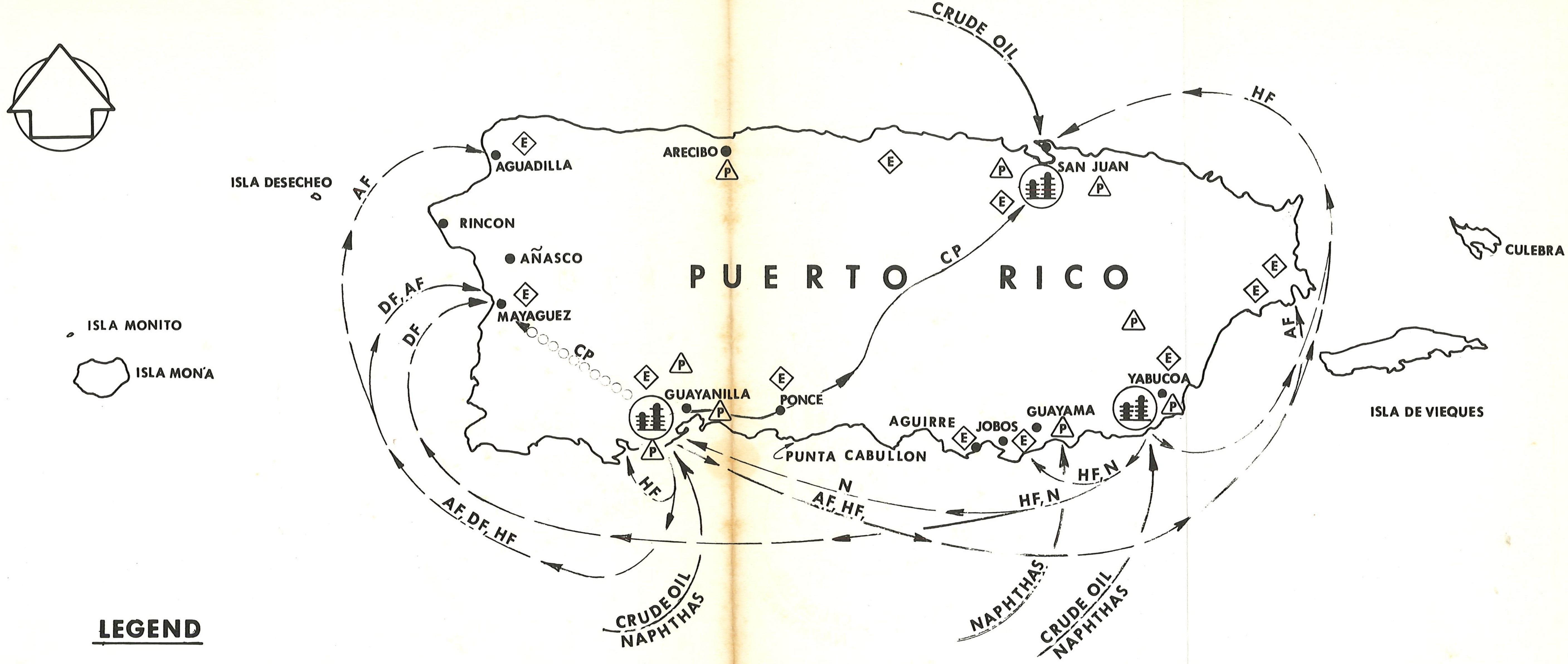
PUERTO RICO INDUSTRIAL DEVELOPMENT COMPANY
COMMONWEALTH OF PUERTO RICO

SITE SCREENING STUDY
DEEP WATER PORT & INDUSTRIAL COMPLEX

LOCATION PLAN
SCREENING STUDY SITES

DATE: AUG. 31, 1973

FIG. NO. 8



LEGEND

——→	EXISTING PRODUCT PIPELINE
○○○○○○○○ ○➤	TANK TRUCKAGE
— — — —→	BARGE TANKER ROUTE
●	CITY
E	ELECTRICAL POWER PLANT
P	PETROCHEMICAL PLANT
	EXISTING REFINING CENTER

AF - AVIATION FUELS
DF - DISTILLATE FUELS
HF - HEAVY FUELS
N - UNFINISHED NAPHTHAS
CP - CONSUMER PRODUCTS
ALT. - ALTERNATE METHOD

0 5 10 15 20
SCALE IN NAUTICAL MILES

VAN HOUTEN ASSOCIATES, INC.
CONSULTING ENGINEERS, NEW YORK

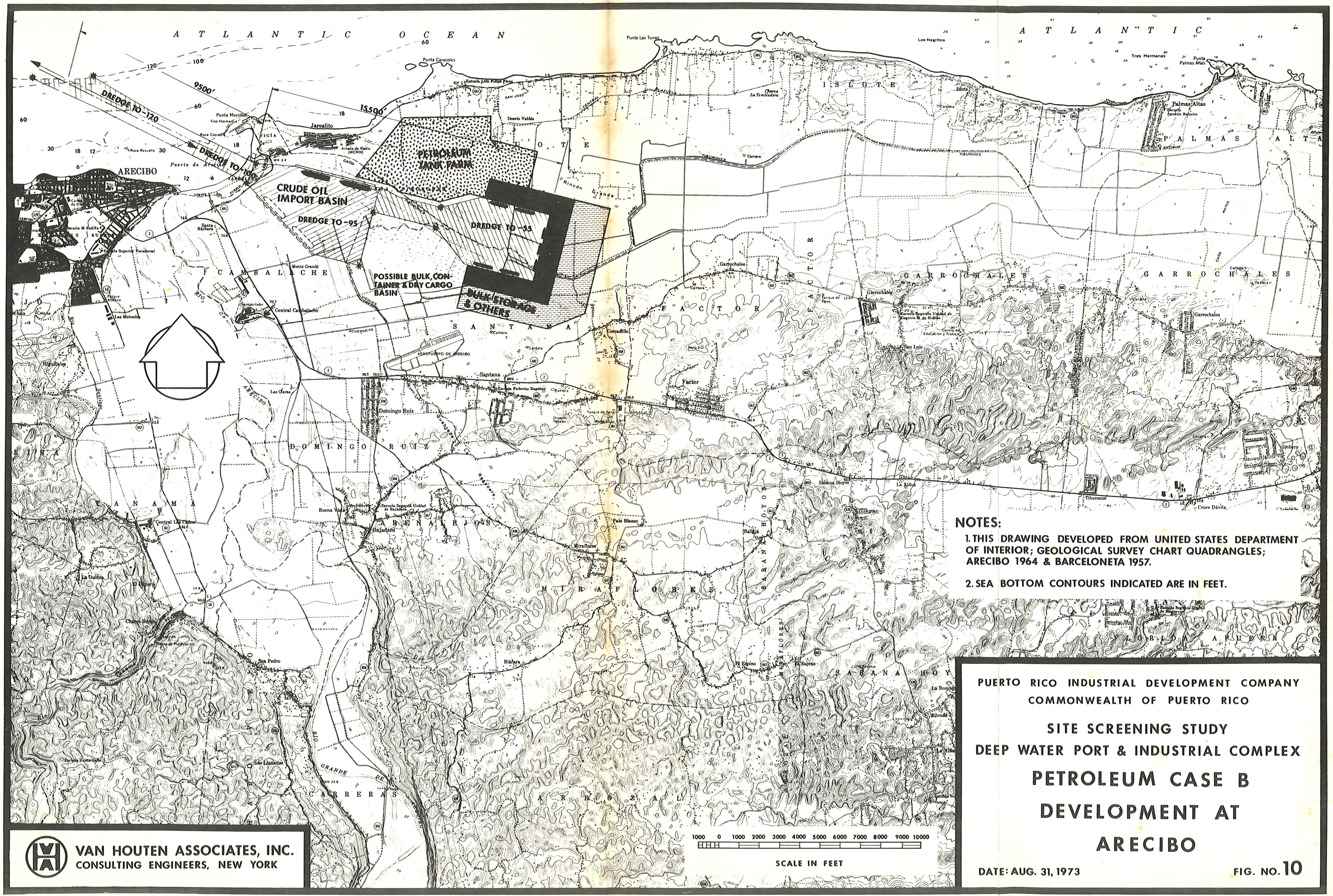
PUERTO RICO INDUSTRIAL DEVELOPMENT COMPANY
COMMONWEALTH OF PUERTO RICO

SITE SCREENING STUDY
DEEP WATER PORT & INDUSTRIAL COMPLEX

PRESENT PETROLEUM PRODUCT
DISTRIBUTION PATTERN

DATE: AUG. 31, 1973

FIG. NO. 9



NOTES:

1. THIS DRAWING DEVELOPED FROM UNITED STATES DEPARTMENT OF INTERIOR; GEOLOGICAL SURVEY CHART QUADRANGLES; ARECIBO 1964 & BARCELONETA 1957.
2. SEA BOTTOM CONTOURS INDICATED ARE IN FEET.

1000 0 1000 2000 3000 4000 5000 6000 7000 8000 9000 10000

SCALE IN FEET

VAN HOUTEN ASSOCIATES, INC.
CONSULTING ENGINEERS, NEW YORK

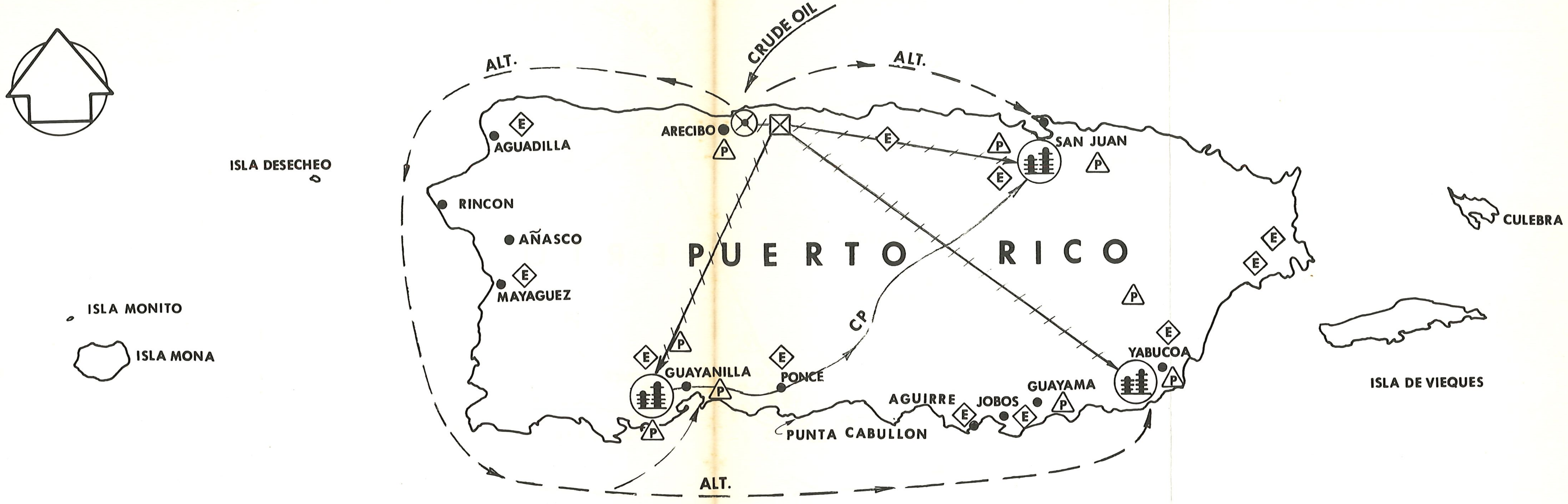
PUERTO RICO INDUSTRIAL DEVELOPMENT COMPANY
COMMONWEALTH OF PUERTO RICO

SITE SCREENING STUDY
DEEP WATER PORT & INDUSTRIAL COMPLEX

PETROLEUM CASE B DEVELOPMENT AT ARECIBO

DATE: AUG. 31, 1973

FIG. NO. 10



LEGEND

⟶	EXISTING PRODUCT PIPELINE
─o─o─o→	NEW PRODUCT PIPELINE
─/─/─/→	NEW CRUDE OIL PIPELINE
ooooooooo→	TANK TRUCKAGE
── ── ──→	BARGE TANKER ROUTE
●	CITY
Ⓔ	ELECTRICAL POWER PLANT
Ⓟ	PETROCHEMICAL PLANT
◉	EXISTING REFINING CENTER
⊗	NEW DEEP WATER CRUDE OIL TERMINAL
☒	NEW CRUDE OIL DISTRIBUTION CENTER
HF	HEAVY FUELS
N	UNFINISHED NAPHTHAS
CP	CONSUMER PRODUCTS
ALT.	ALTERNATE METHOD

0 5 10 15 20
SCALE IN NAUTICAL MILES

VAN HOUTEN ASSOCIATES, INC.
CONSULTING ENGINEERS, NEW YORK

PUERTO RICO INDUSTRIAL DEVELOPMENT COMPANY
COMMONWEALTH OF PUERTO RICO

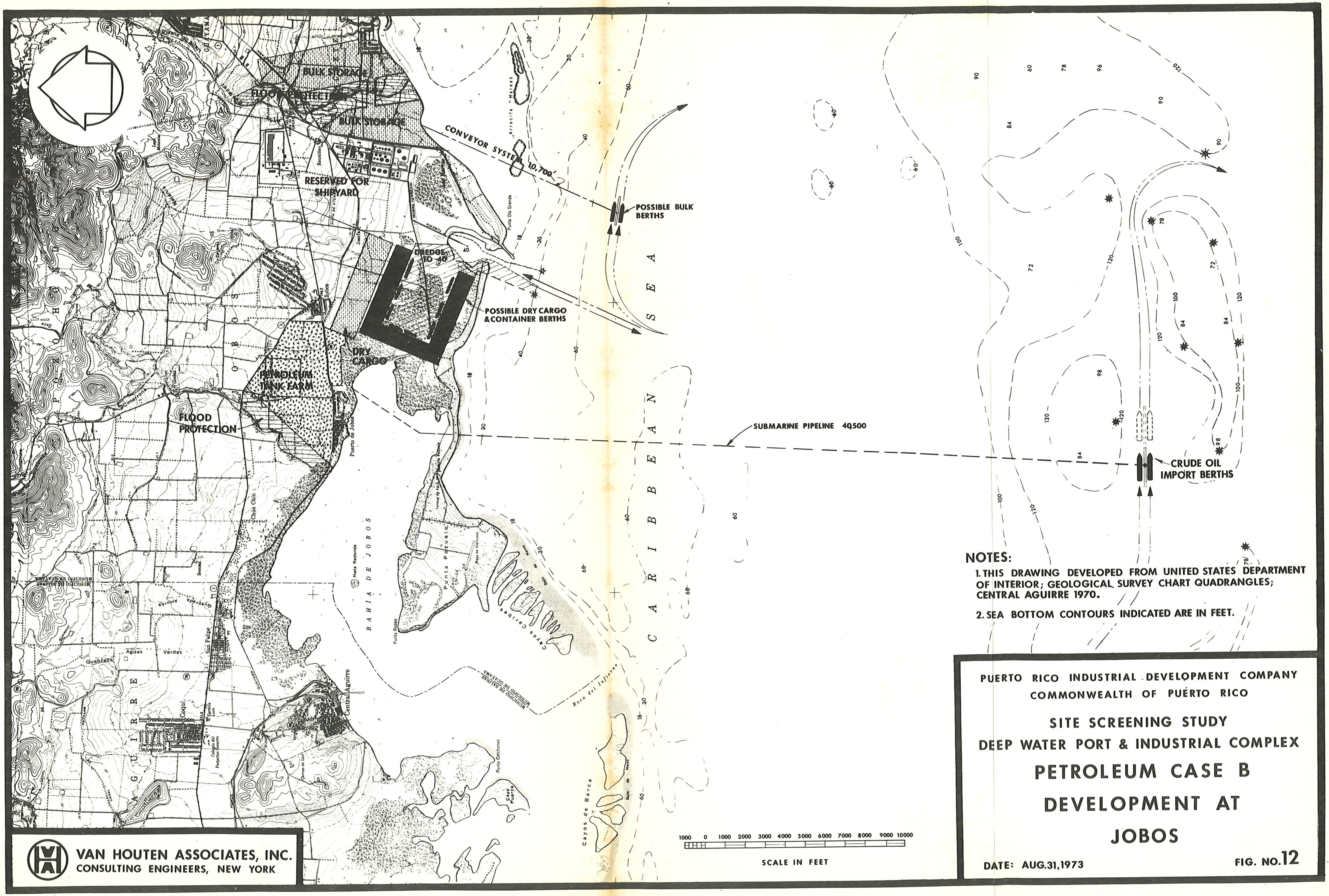
SITE SCREENING STUDY
DEEP WATER PORT & INDUSTRIAL COMPLEX

PETROLEUM CASE B

DISTRIBUTION FROM ARECIBO

DATE: AUG. 31, 1973

FIG. NO. 11



NOTES:

1. THIS DRAWING DEVELOPED FROM UNITED STATES DEPARTMENT OF INTERIOR; GEOLOGICAL SURVEY CHART QUADRANGLES; CENTRAL AGUIRRE 1970.
2. SEA BOTTOM CONTOURS INDICATED ARE IN FEET.

PUERTO RICO INDUSTRIAL DEVELOPMENT COMPANY
COMMONWEALTH OF PUERTO RICO

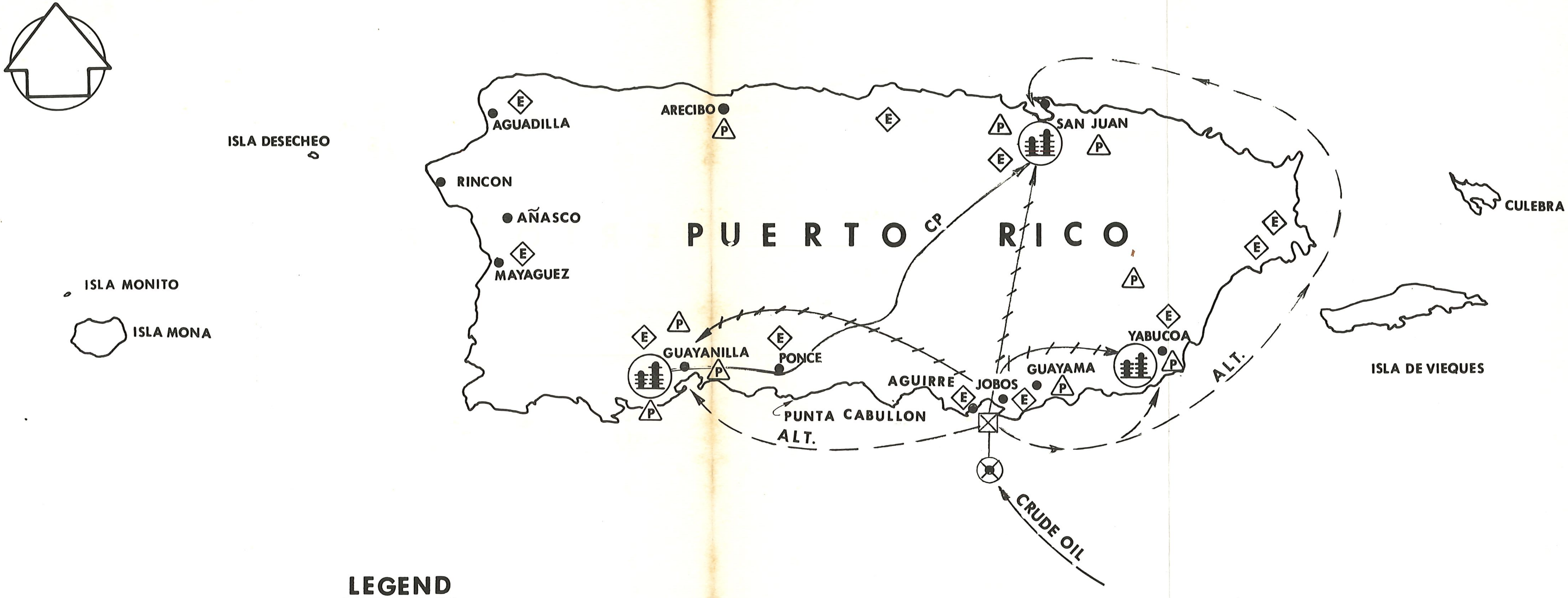
SITE SCREENING STUDY
DEEP WATER PORT & INDUSTRIAL COMPLEX

PETROLEUM CASE B
DEVELOPMENT AT
JOBOS

DATE: AUG.31,1973

FIG. NO.12

VAN HOUTEN ASSOCIATES, INC.
CONSULTING ENGINEERS, NEW YORK



LEGEND

⟶	EXISTING PRODUCT PIPELINE
—o—o—o→	NEW PRODUCT PIPELINE
—/—/—/→	NEW CRUDE OIL PIPELINE
ooooooooo→	TANK TRUCKAGE
— — — →	BARGE TANKER ROUTE
●	CITY
◈ E	ELECTRICAL POWER PLANT
△ P	PETROCHEMICAL PLANT
◉	EXISTING REFINING CENTER
⊗	NEW DEEP WATER CRUDE OIL TERMINAL
☒	NEW CRUDE OIL DISTRIBUTION CENTER
HF	HEAVY FUELS
N	UNFINISHED NAPHTHAS
CP	CONSUMER PRODUCTS
ALT.	ALTERNATE METHOD

0 5 10 15 20
SCALE IN NAUTICAL MILES

VAN HOUTEN ASSOCIATES, INC.
CONSULTING ENGINEERS, NEW YORK

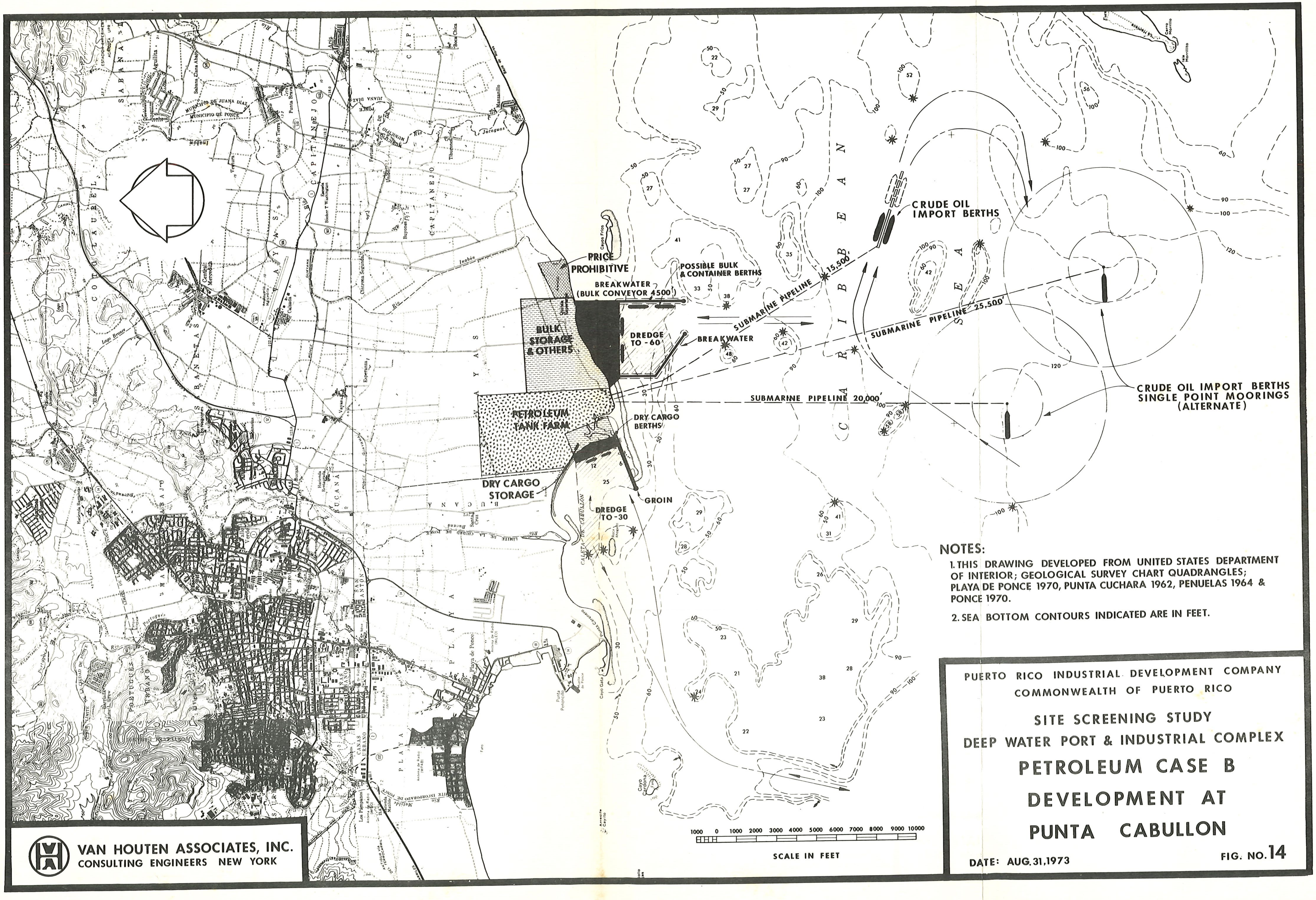
PUERTO RICO INDUSTRIAL DEVELOPMENT COMPANY
COMMONWEALTH OF PUERTO RICO

SITE SCREENING STUDY
DEEP WATER PORT & INDUSTRIAL COMPLEX

PETROLEUM CASE B
DISTRIBUTION FROM JOBOS

DATE: AUG. 31, 1973

FIG. NO. 13



NOTES:

1. THIS DRAWING DEVELOPED FROM UNITED STATES DEPARTMENT OF INTERIOR; GEOLOGICAL SURVEY CHART QUADRANGLES; PLAYA DE PONCE 1970, PUNTA CUCHARA 1962, PENUELAS 1964 & PONCE 1970.
2. SEA BOTTOM CONTOURS INDICATED ARE IN FEET.

PUERTO RICO INDUSTRIAL DEVELOPMENT COMPANY
COMMONWEALTH OF PUERTO RICO

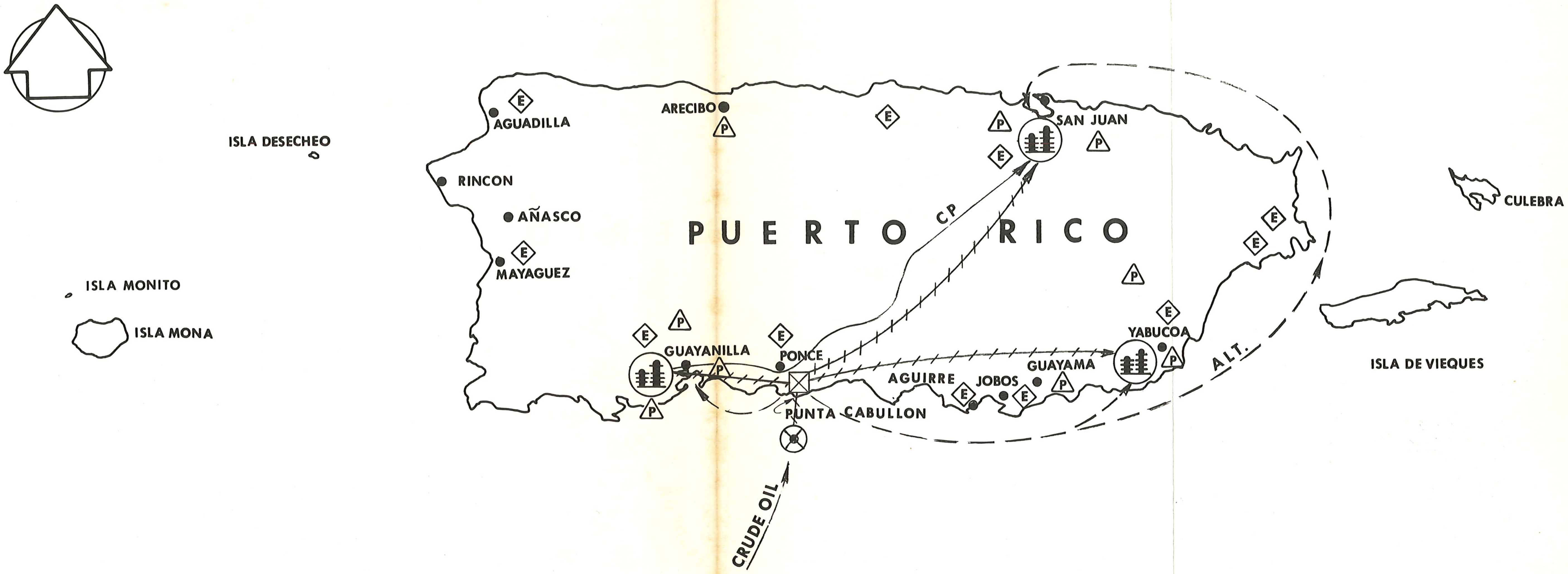
SITE SCREENING STUDY
DEEP WATER PORT & INDUSTRIAL COMPLEX

PETROLEUM CASE B DEVELOPMENT AT PUNTA CABULLON

DATE: AUG. 31, 1973

FIG. NO. 14

VAN HOUTEN ASSOCIATES, INC.
CONSULTING ENGINEERS NEW YORK



LEGEND

——→	EXISTING PRODUCT PIPELINE	E	ELECTRICAL POWER PLANT
—○—○—○→	NEW PRODUCT PIPELINE	P	PETROCHEMICAL PLANT
—/—/—/→	NEW CRUDE OIL PIPELINE		EXISTING REFINING CENTER
○○○○○○○○○→	TANK TRUCKAGE	⊗	NEW DEEP WATER CRUDE OIL TERMINAL
— — — →	BARGE TANKER ROUTE	☒	NEW CRUDE OIL DISTRIBUTION CENTER
●	CITY	HF	HEAVY FUELS
		N	UNFINISHED NAPHTHAS
		CP	CONSUMER PRODUCTS
		ALT.	ALTERNATE METHOD

0 5 10 15 20
SCALE IN NAUTICAL MILES

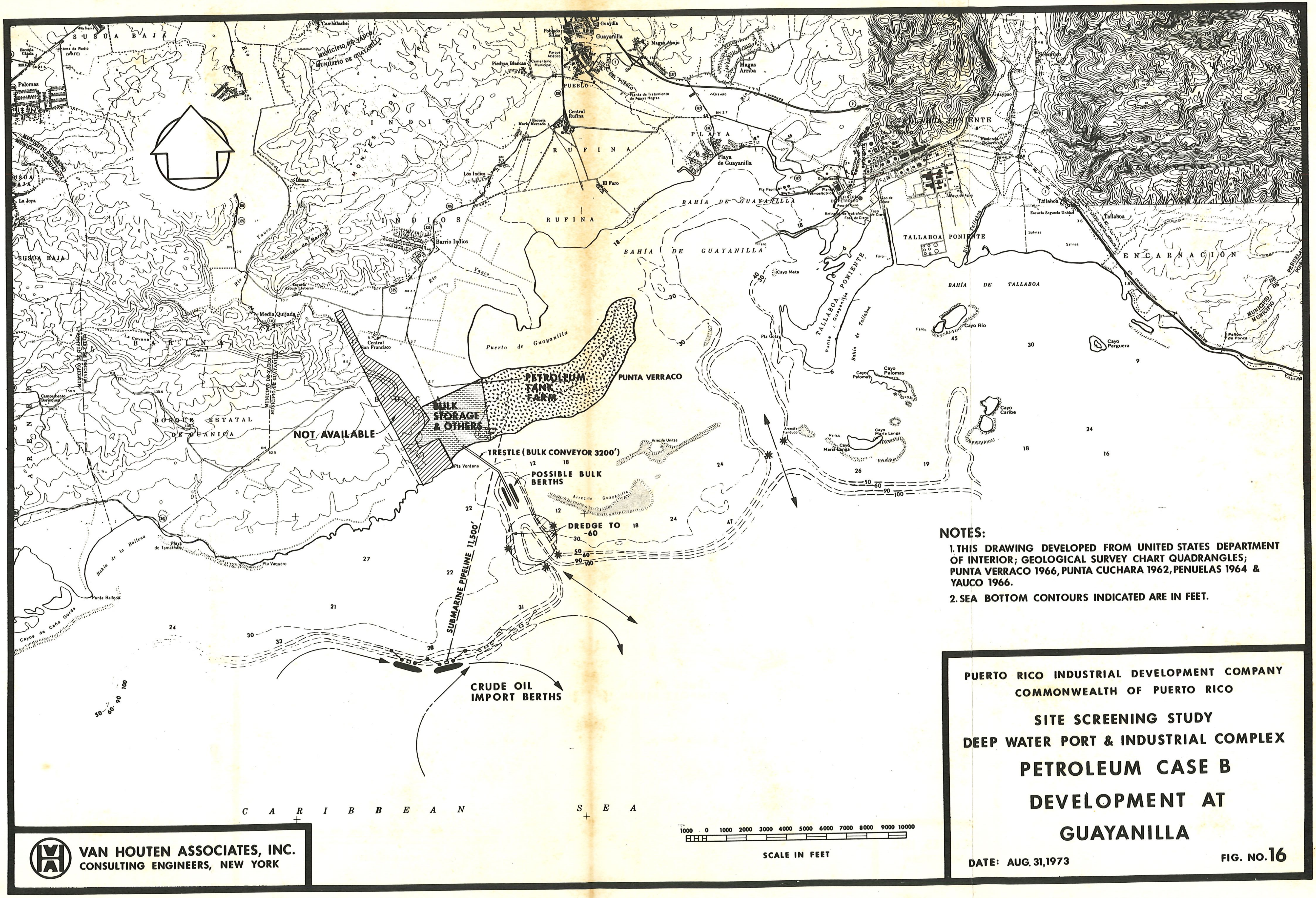
VAN HOUTEN ASSOCIATES, INC.
CONSULTING ENGINEERS, NEW YORK

PUERTO RICO INDUSTRIAL DEVELOPMENT COMPANY
COMMONWEALTH OF PUERTO RICO

SITE SCREENING STUDY
DEEP WATER PORT & INDUSTRIAL COMPLEX

PETROLEUM CASE B
DISTRIBUTION FROM
PUNTA CABULLON

DATE: AUG. 31, 1973 FIG. NO. 15



NOTES:

1. THIS DRAWING DEVELOPED FROM UNITED STATES DEPARTMENT OF INTERIOR; GEOLOGICAL SURVEY CHART QUADRANGLES; PUNTA VERRACO 1966, PUNTA CUCHARA 1962, PENUELAS 1964 & YAUCO 1966.
2. SEA BOTTOM CONTOURS INDICATED ARE IN FEET.

PUERTO RICO INDUSTRIAL DEVELOPMENT COMPANY
COMMONWEALTH OF PUERTO RICO

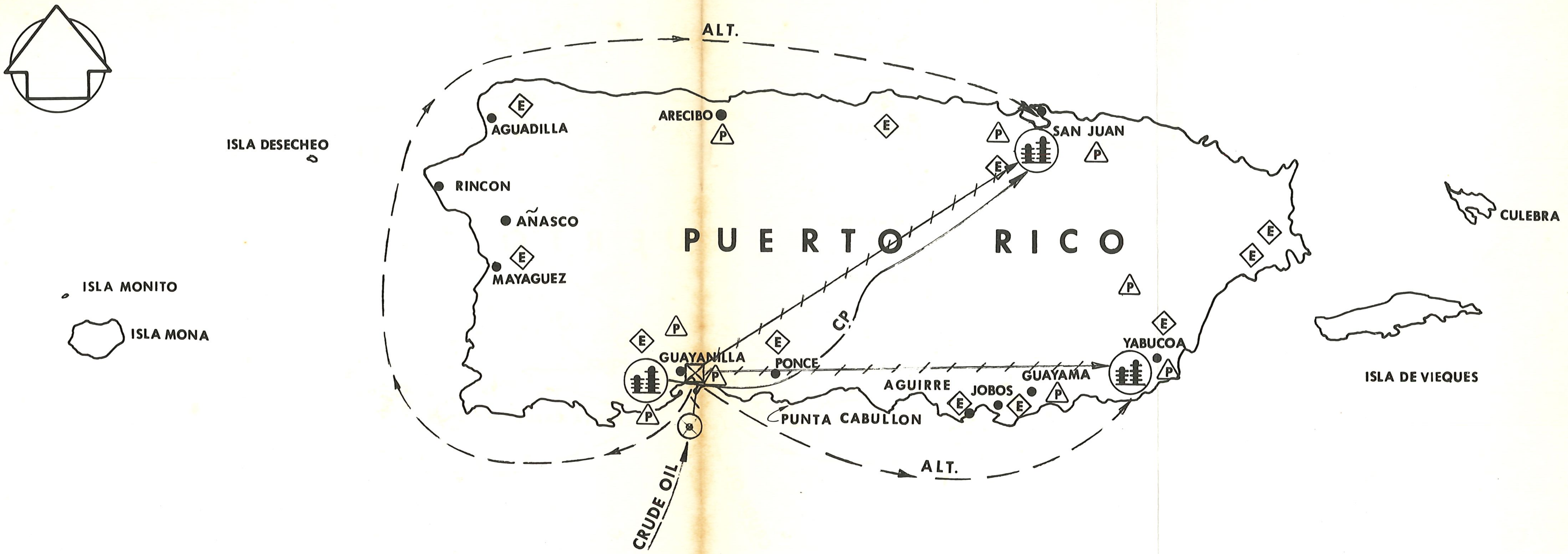
SITE SCREENING STUDY
DEEP WATER PORT & INDUSTRIAL COMPLEX

PETROLEUM CASE B
DEVELOPMENT AT
GUAYANILLA

DATE: AUG. 31, 1973

FIG. NO. 16

VAN HOUTEN ASSOCIATES, INC.
CONSULTING ENGINEERS, NEW YORK



LEGEND

- ——→ EXISTING PRODUCT PIPELINE
- —o—o—o→ NEW PRODUCT PIPELINE
- ooooooooo→ TANK TRUCKAGE
- — — — → BARGE TANKER ROUTE
- ● CITY
- ◇E ELECTRICAL POWER PLANT
- △P PETROCHEMICAL PLANT
- EXISTING REFINING CENTER
- ⊗ NEW DEEP WATER CRUDE OIL TERMINAL
- ☒ NEW CRUDE OIL DISTRIBUTION CENTER
- HF HEAVY FUELS
- N UNFINISHED NAPTHAS
- CP CONSUMER PRODUCTS
- ALT. ALTERNATE METHODS

0 5 10 15 20
SCALE IN NAUTICAL MILES

VAN HOUTEN ASSOCIATES, INC.
CONSULTING ENGINEERS, NEW YORK

PUERTO RICO INDUSTRIAL DEVELOPMENT COMPANY
COMMONWEALTH OF PUERTO RICO

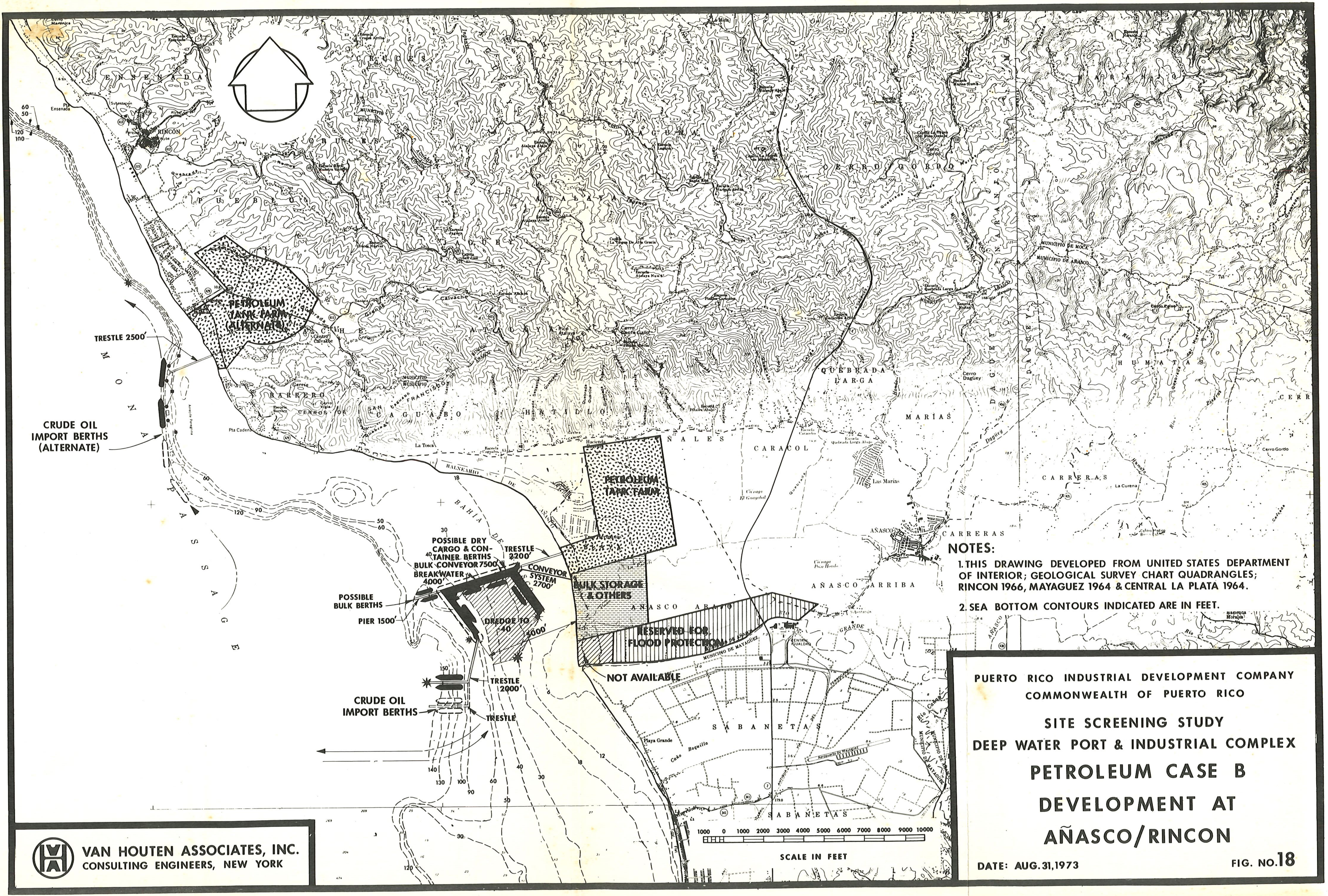
SITE SCREENING STUDY
DEEP WATER PORT & INDUSTRIAL COMPLEX

PETROLEUM CASE B

DISTRIBUTION FROM GUAYANILLA

DATE: AUG. 31, 1973

FIG. NO. 17



NOTES:

1. THIS DRAWING DEVELOPED FROM UNITED STATES DEPARTMENT OF INTERIOR; GEOLOGICAL SURVEY CHART QUADRANGLES; RINCON 1966, MAYAGUEZ 1964 & CENTRAL LA PLATA 1964.
2. SEA BOTTOM CONTOURS INDICATED ARE IN FEET.

PUERTO RICO INDUSTRIAL DEVELOPMENT COMPANY
COMMONWEALTH OF PUERTO RICO

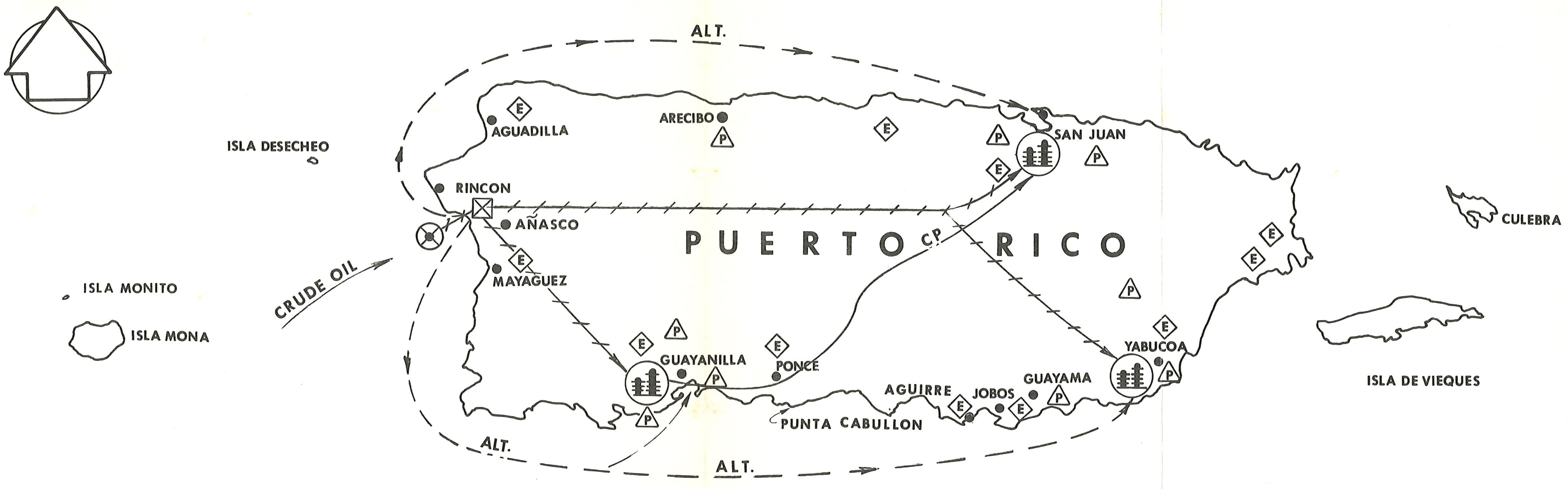
SITE SCREENING STUDY
DEEP WATER PORT & INDUSTRIAL COMPLEX

PETROLEUM CASE B
DEVELOPMENT AT
AÑASCO/RINCON

DATE: AUG. 31, 1973

FIG. NO. 18

VAN HOUTEN ASSOCIATES, INC.
CONSULTING ENGINEERS, NEW YORK



LEGEND

——→	EXISTING PRODUCT PIPELINE
–○–○–○→	NEW PRODUCT PIPELINE
–/–/–/→	NEW CRUDE OIL PIPELINE
○○○○○○○○○→	TANK TRUCKAGE
– – – –→	BARGE TANKER ROUTE
●	CITY

Ⓔ	ELECTRICAL POWER PLANT
Ⓟ	PETROCHEMICAL PLANT
◉	EXISTING REFINING CENTER
⊗	NEW DEEP WATER CRUDE OIL TERMINAL
☒	NEW CRUDE OIL DISTRIBUTION CENTER
HF	HEAVY FUELS
N	UNFINISHED NAPHTHAS
CP	CONSUMER PRODUCTS
ALT.	ALTERNATE METHOD

0 5 10 15 20
SCALE IN NAUTICAL MILES

VAN HOUTEN ASSOCIATES, INC.
CONSULTING ENGINEERS, NEW YORK

PUERTO RICO INDUSTRIAL DEVELOPMENT COMPANY
COMMONWEALTH OF PUERTO RICO

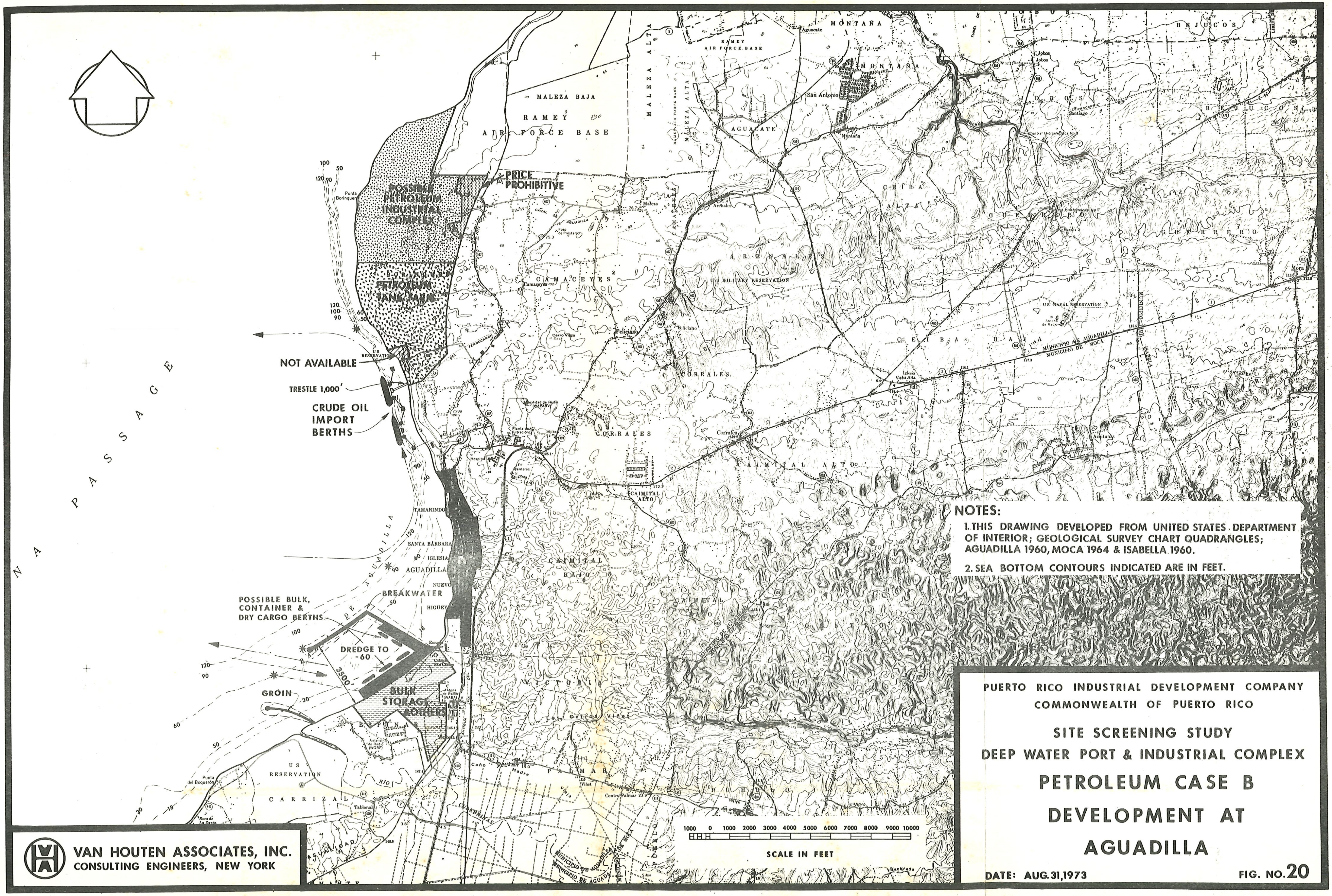
SITE SCREENING STUDY
DEEP WATER PORT & INDUSTRIAL COMPLEX

PETROLEUM CASE B

DISTRIBUTION FROM AÑASCO/RINCON

DATE: AUG.31,1973

FIG.NO.19



NOTES:

1. THIS DRAWING DEVELOPED FROM UNITED STATES DEPARTMENT OF INTERIOR; GEOLOGICAL SURVEY CHART QUADRANGLES; AGUADILLA 1960, MOCA 1964 & ISABELLA 1960.
2. SEA BOTTOM CONTOURS INDICATED ARE IN FEET.

PUERTO RICO INDUSTRIAL DEVELOPMENT COMPANY
COMMONWEALTH OF PUERTO RICO

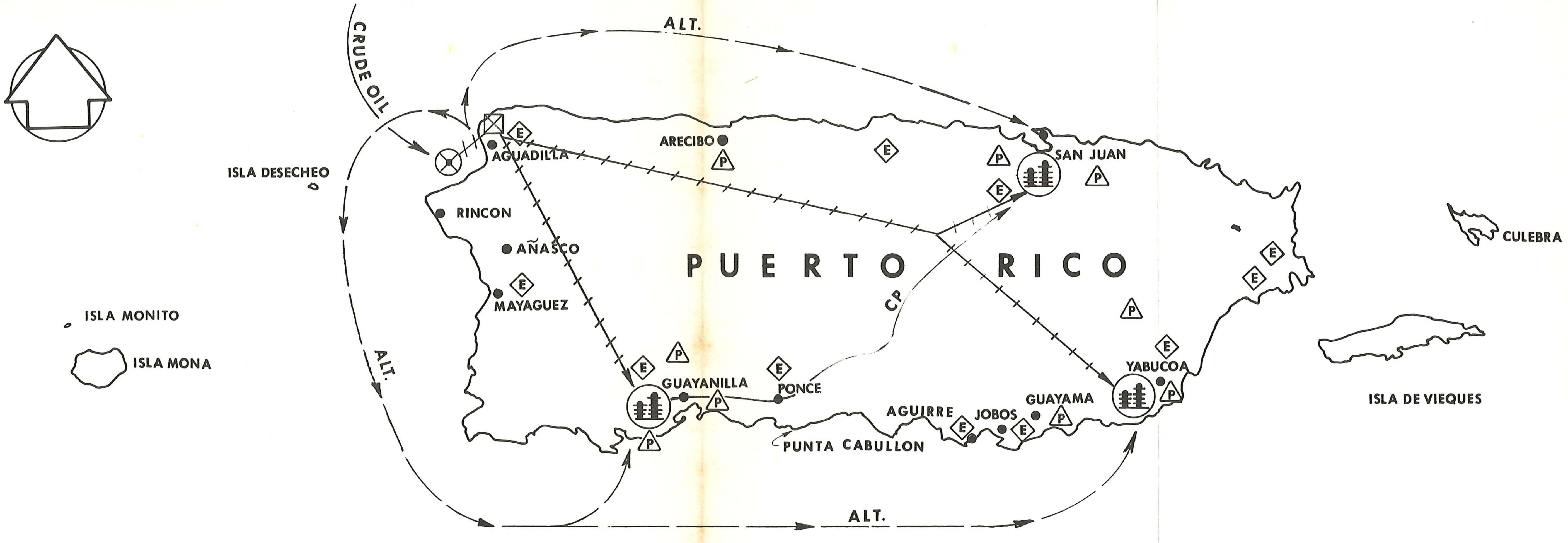
SITE SCREENING STUDY
DEEP WATER PORT & INDUSTRIAL COMPLEX

PETROLEUM CASE B DEVELOPMENT AT AGUADILLA

DATE: AUG. 31, 1973

FIG. NO. 20

VAN HOUTEN ASSOCIATES, INC.
CONSULTING ENGINEERS, NEW YORK



LEGEND

——→	EXISTING PRODUCT PIPELINE
—o—o—o→	NEW PRODUCT PIPELINE
—/—/—/→	NEW CRUDE OIL PIPELINE
ooooooooo→	TANK TRUCKAGE
— — — →	BARGE TANKER ROUTE
●	CITY
E	ELECTRICAL POWER PLANT
P	PETROCHEMICAL PLANT
	EXISTING REFINING CENTER
⊗	NEW DEEP WATER CRUDE OIL TERMINAL
☒	NEW CRUDE OIL DISTRIBUTION CENTER
HF	HEAVY FUELS
N	UNFINISHED NAPHTHAS
CP	CONSUMER PRODUCTS
ALT.	ALTERNATE METHOD

0 5 10 15 20
SCALE IN NAUTICAL MILES

VAN HOUTEN ASSOCIATES, INC.
CONSULTING ENGINEERS, NEW YORK

PUERTO RICO INDUSTRIAL DEVELOPMENT COMPANY
COMMONWEALTH OF PUERTO RICO

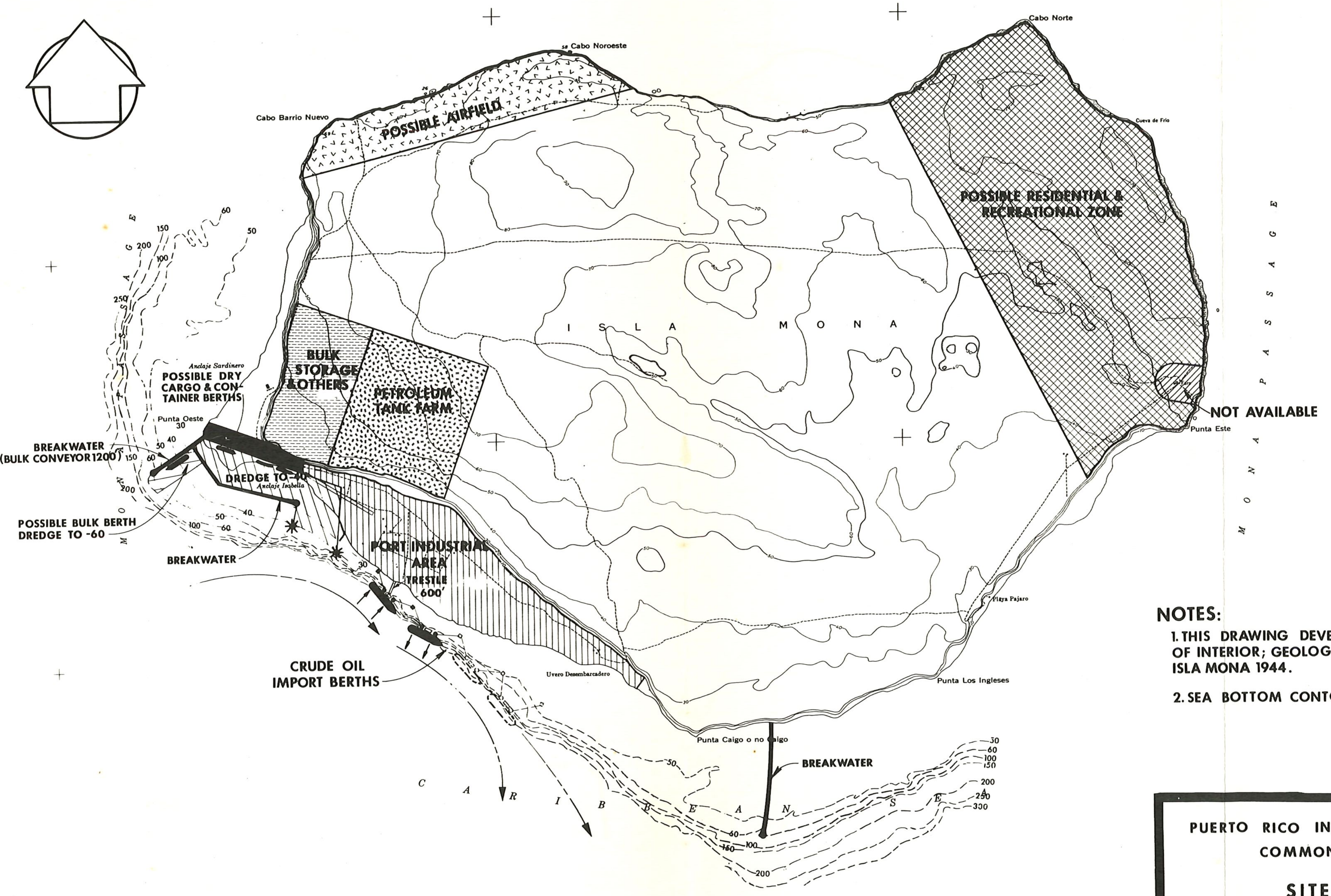
SITE SCREENING STUDY
DEEP WATER PORT & INDUSTRIAL COMPLEX

PETROLEUM CASE B

DISTRIBUTION FROM AGUADILLA

DATE: AUG. 31, 1973

FIG. NO. 21



1000 0 1000 2000 3000 4000 5000 6000 7000 8000 9000 10000

SCALE IN FEET

NOTES:

1. THIS DRAWING DEVELOPED FROM UNITED STATES DEPARTMENT OF INTERIOR; GEOLOGICAL SURVEY CHART QUADRANGLES; ISLA MONA 1944.
2. SEA BOTTOM CONTOURS INDICATED ARE IN FEET.

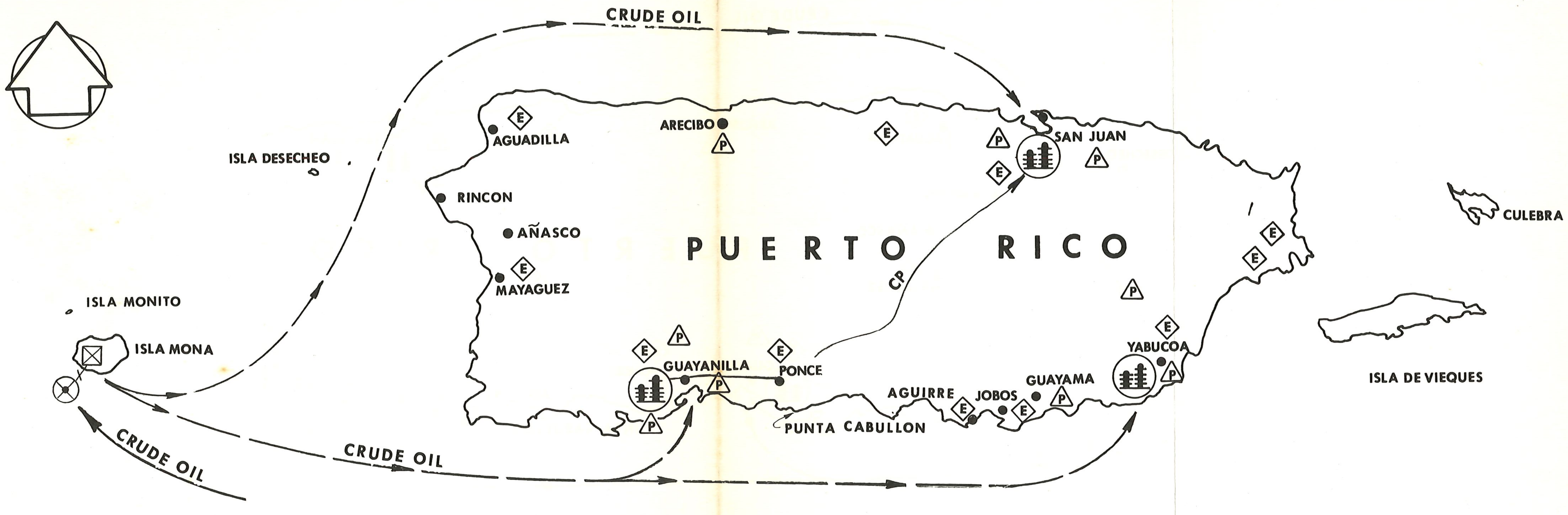
PUERTO RICO INDUSTRIAL DEVELOPMENT COMPANY
COMMONWEALTH OF PUERTO RICO

SITE SCREENING STUDY
DEEP WATER PORT & INDUSTRIAL COMPLEX

PETROLEUM CASE B
DEVELOPMENT AT
ISLA MONA

DATE: AUG. 31, 1973 FIG. NO. 22

VAN HOUTEN ASSOCIATES, INC.
CONSULTING ENGINEERS, NEW YORK



LEGEND

⟶	EXISTING PRODUCT PIPELINE	◇E	ELECTRICAL POWER PLANT
—o—o—o→	NEW PRODUCT PIPELINE	△P	PETROCHEMICAL PLANT
—/—/—/→	NEW CRUDE OIL PIPELINE	◎	EXISTING REFINING CENTER
ooooooooo→	TANK TRUCKAGE	⊗	NEW DEEP WATER CRUDE OIL TERMINAL
— — — →	BARGE TANKER ROUTE	☒	NEW CRUDE OIL DISTRIBUTION CENTER
●	CITY	HF	HEAVY FUELS
		N	UNFINISHED NAPHTHAS
		CP	CONSUMER PRODUCTS
		ALT.	ALTERNATE METHOD

0 5 10 15 20
SCALE IN NAUTICAL MILES

VAN HOUTEN ASSOCIATES, INC.
CONSULTING ENGINEERS, NEW YORK

PUERTO RICO INDUSTRIAL DEVELOPMENT COMPANY
COMMONWEALTH OF PUERTO RICO

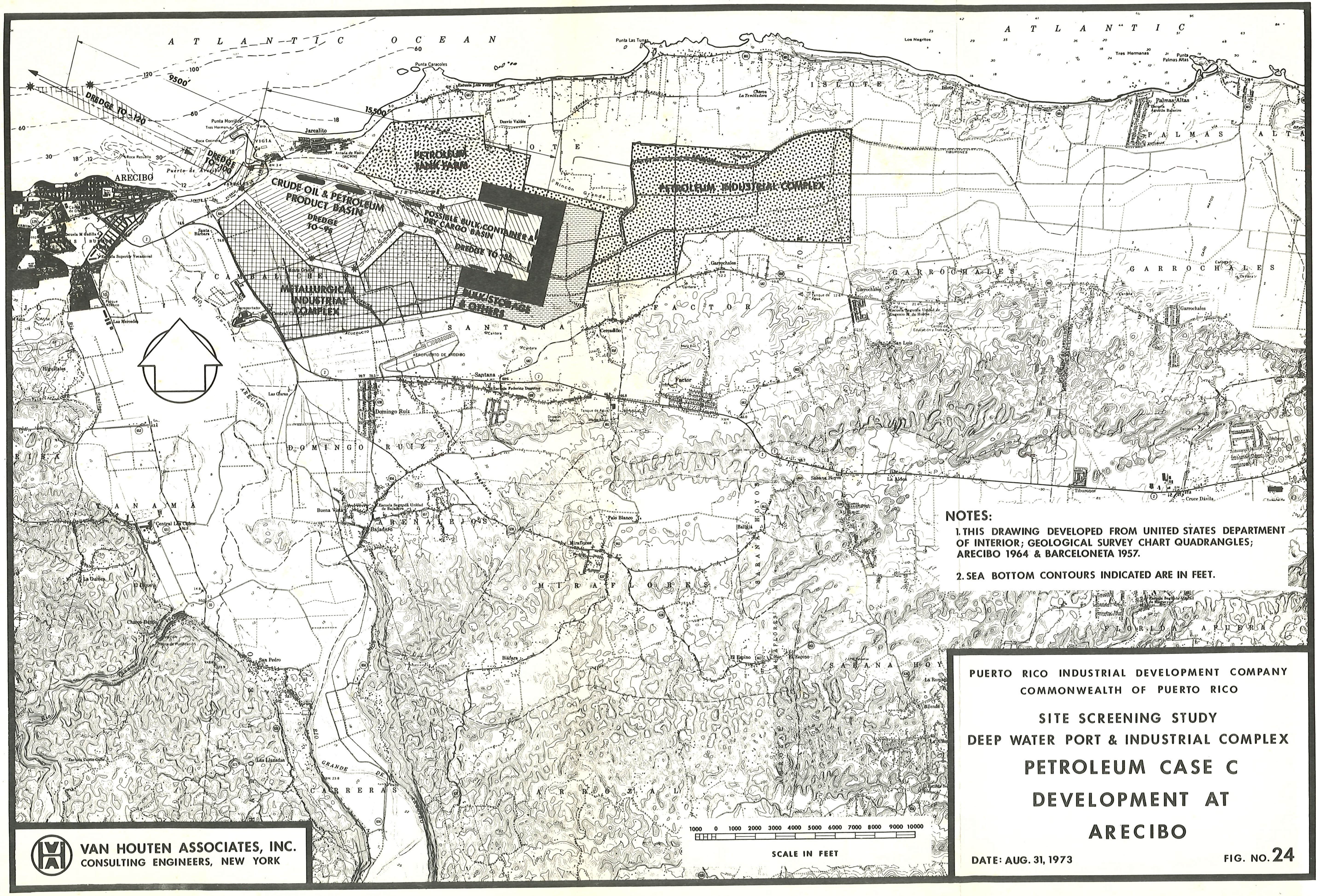
SITE SCREENING STUDY
DEEP WATER PORT & INDUSTRIAL COMPLEX

PETROLEUM CASE B

DISTRIBUTION FROM ISLA MONA

DATE: AUG.31,1973

FIG.NO. 23



NOTES:

1. THIS DRAWING DEVELOPED FROM UNITED STATES DEPARTMENT OF INTERIOR; GEOLOGICAL SURVEY CHART QUADRANGLES; ARECIBO 1964 & BARCELONETA 1957.
2. SEA BOTTOM CONTOURS INDICATED ARE IN FEET.

PUERTO RICO INDUSTRIAL DEVELOPMENT COMPANY
COMMONWEALTH OF PUERTO RICO

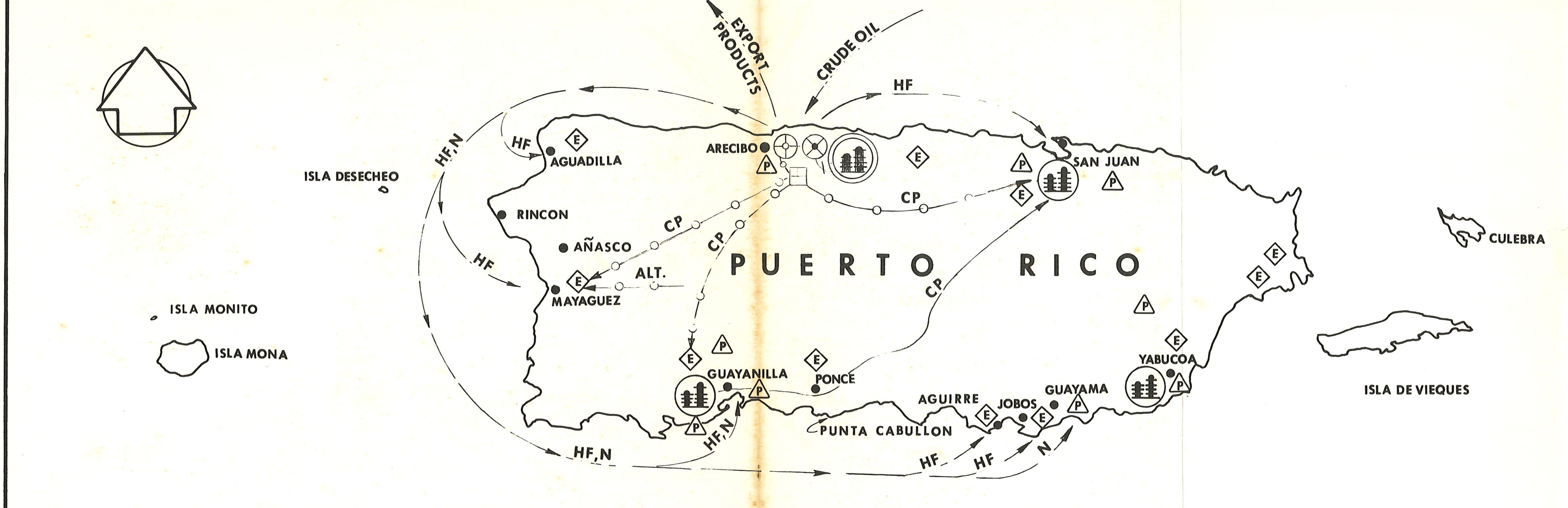
SITE SCREENING STUDY
DEEP WATER PORT & INDUSTRIAL COMPLEX

PETROLEUM CASE C DEVELOPMENT AT ARECIBO

DATE: AUG. 31, 1973

FIG. NO. 24

VAN HOUTEN ASSOCIATES, INC.
CONSULTING ENGINEERS, NEW YORK



LEGEND

——→	EXISTING PRODUCT PIPELINE		EXISTING REFINING CENTER
—o—o—o→	NEW PRODUCT PIPELINE		NEW REFINING CENTER
—/—/—/→	NEW CRUDE OIL PIPELINE	•	CITY
— — — →	BARGE TANKER ROUTE	⊕	NEW DEEP WATER PRODUCT TERMINAL
oooooooo→	TANK TRUCKAGE	⊗	NEW DEEP WATER CRUDE OIL TERMINAL
◈ E	ELECTRICAL POWER PLANT	⊞	NEW PRODUCT DISTRIBUTION CENTER
△ P	PETROCHEMICAL PLANT	☒	NEW CRUDE OIL DISTRIBUTION CENTER
		HF	HEAVY FUELS
		N	UNFINISHED NAPHTHAS
		CP	CONSUMER PRODUCTS
		ALT.	ALTERNATE METHOD

VAN HOUTEN ASSOCIATES, INC.
CONSULTING ENGINEERS, NEW YORK

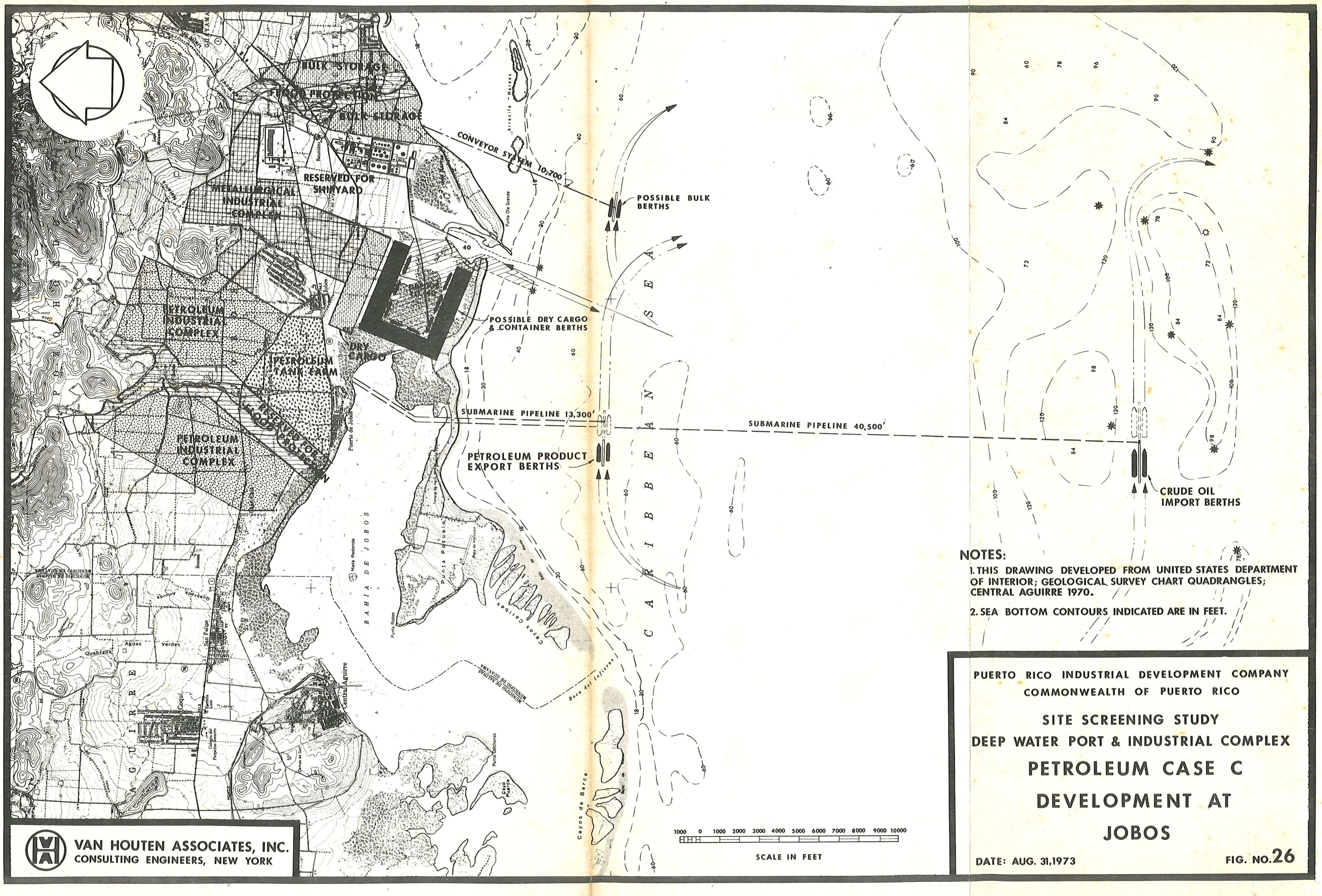
PUERTO RICO INDUSTRIAL DEVELOPMENT COMPANY
COMMONWEALTH OF PUERTO RICO

SITE SCREENING STUDY
DEEP WATER PORT & INDUSTRIAL COMPLEX

PETROLEUM CASE C
DISTRIBUTION FROM ARECIBO

DATE: AUG. 31, 1973

FIG. NO. 25



NOTES:

1. THIS DRAWING DEVELOPED FROM UNITED STATES DEPARTMENT OF INTERIOR; GEOLOGICAL SURVEY CHART QUADRANGLES; CENTRAL AGUIRRE 1970.
2. SEA BOTTOM CONTOURS INDICATED ARE IN FEET.

PUERTO RICO INDUSTRIAL DEVELOPMENT COMPANY
COMMONWEALTH OF PUERTO RICO

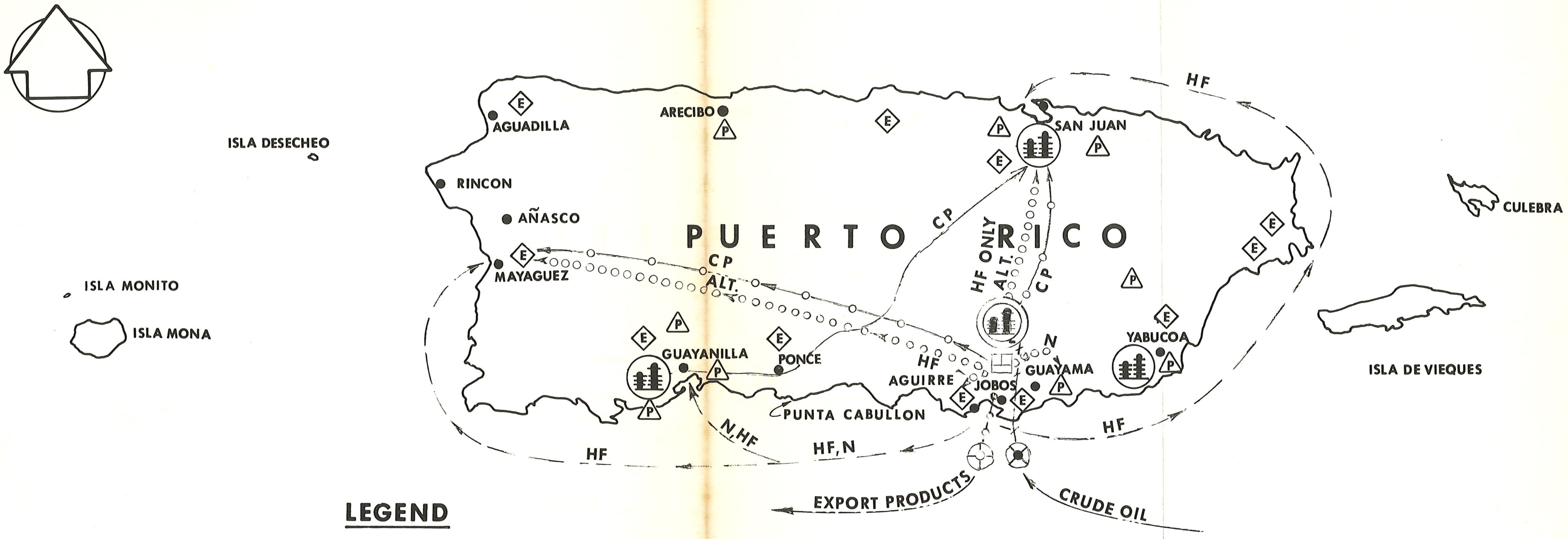
SITE SCREENING STUDY
DEEP WATER PORT & INDUSTRIAL COMPLEX

PETROLEUM CASE C
DEVELOPMENT AT
JOBOS

DATE: AUG. 31,1973

FIG. NO.26

VAN HOUTEN ASSOCIATES, INC.
CONSULTING ENGINEERS, NEW YORK



LEGEND

——→	EXISTING PRODUCT PIPELINE
—o—o—o→	NEW PRODUCT PIPELINE
—/—/—/→	NEW CRUDE OIL PIPELINE
— — —→	BARGE TANKER ROUTE
oooooooo→	TANK TRUCKAGE
◇E	ELECTRICAL POWER PLANT
△P	PETROCHEMICAL PLANT
	EXISTING REFINING CENTER
	NEW REFINING CENTER
●	CITY
⊕	NEW DEEP WATER PRODUCT TERMINAL
⊗	NEW DEEP WATER CRUDE OIL TERMINAL
⊞	NEW PRODUCT DISTRIBUTION CENTER
☒	NEW CRUDE OIL DISTRIBUTION CENTER
HF	HEAVY FUELS
N	UNFINISHED NAPHTHAS
CP	CONSUMER PRODUCTS
ALT.	ALTERNATE METHOD

0 5 10 15 20
SCALE IN NAUTICAL MILES

VAN HOUTEN ASSOCIATES, INC.
CONSULTING ENGINEERS, NEW YORK

PUERTO RICO INDUSTRIAL DEVELOPMENT COMPANY
COMMONWEALTH OF PUERTO RICO

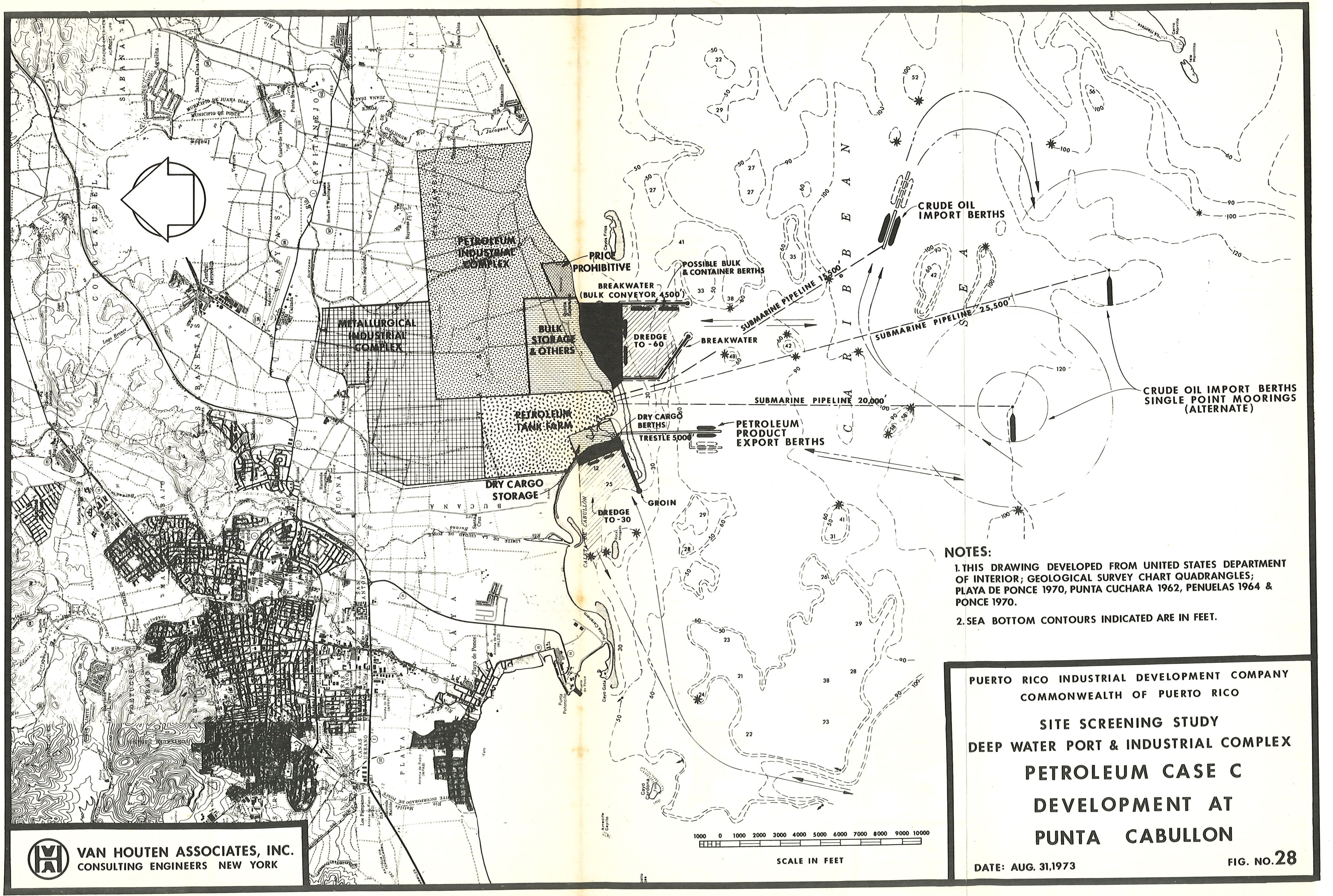
SITE SCREENING STUDY
DEEP WATER PORT & INDUSTRIAL COMPLEX

PETROLEUM CASE C

DISTRIBUTION FROM JOBOS

DATE: AUG.31,1973

FIG.NO. 27


PETROLEUM INDUSTRIAL COMPLEX
PRICE PROHIBITIVE
METALLURGICAL INDUSTRIAL COMPLEX
BULK STORAGE & OTHERS
BREAKWATER (BULK CONVEYOR 4500')
POSSIBLE BULK & CONTAINER BERTHS
DREDGE TO -60
BREAKWATER
PETROLEUM TANK FARM
DRY CARGO STORAGE
DRY CARGO BERTHS
TRESTLE 5000'
PETROLEUM PRODUCT EXPORT BERTHS
GROIN
DREDGE TO -30
SUBMARINE PIPELINE 15,500'
SUBMARINE PIPELINE 25,500'
SUBMARINE PIPELINE 20,000'
CRUDE OIL IMPORT BERTHS
CRUDE OIL IMPORT BERTHS SINGLE POINT MOORINGS (ALTERNATE)
CARIBBEAN SEA
CALETA DE CABULLON
PLAYA DE PONCE
1000 0 1000 2000 3000 4000 5000 6000 7000 8000 9000 10000
SCALE IN FEET

NOTES:

1. THIS DRAWING DEVELOPED FROM UNITED STATES DEPARTMENT OF INTERIOR; GEOLOGICAL SURVEY CHART QUADRANGLES; PLAYA DE PONCE 1970, PUNTA CUCHARA 1962, PENUELAS 1964 & PONCE 1970.
2. SEA BOTTOM CONTOURS INDICATED ARE IN FEET.

PUERTO RICO INDUSTRIAL DEVELOPMENT COMPANY
COMMONWEALTH OF PUERTO RICO

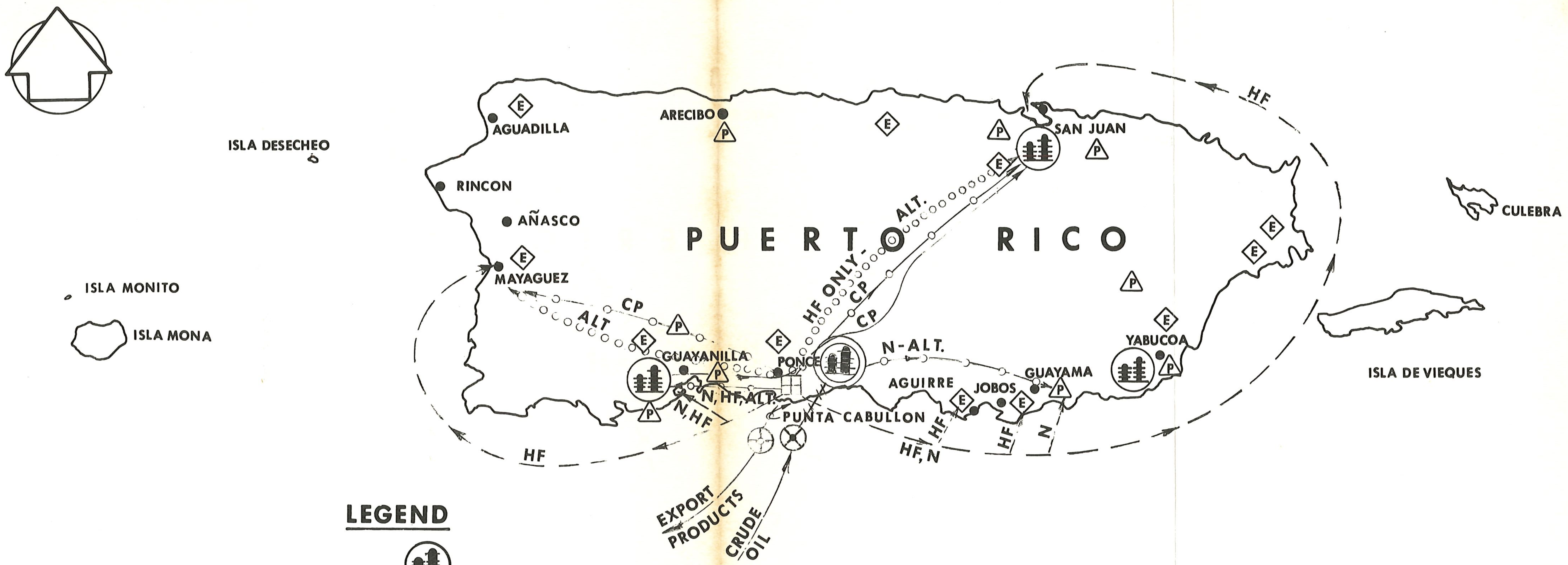
SITE SCREENING STUDY
DEEP WATER PORT & INDUSTRIAL COMPLEX

PETROLEUM CASE C DEVELOPMENT AT PUNTA CABULLON

DATE: AUG. 31,1973

FIG. NO.28

VAN HOUTEN ASSOCIATES, INC.
CONSULTING ENGINEERS NEW YORK



LEGEND

⟶	EXISTING PRODUCT PIPELINE
–o–o–o→	NEW PRODUCT PIPELINE
–/–/–/→	NEW CRUDE OIL PIPELINE
– – – →	BARGE TANKER ROUTE
oooooooo→	TANK TRUCKAGE
E	ELECTRICAL POWER PLANT
P	PETROCHEMICAL PLANT
	EXISTING REFINING CENTER
	NEW REFINING CENTER
●	CITY
⊕	NEW DEEP WATER PRODUCT TERMINAL
⊗	NEW DEEP WATER CRUDE OIL TERMINAL
⊞	NEW PRODUCT DISTRIBUTION CENTER
⊠	NEW CRUDE OIL DISTRIBUTION CENTER
HF	HEAVY FUELS
N	UNFINISHED NAPHTHAS
CP	CONSUMER PRODUCTS
ALT.	ALTERNATE METHOD

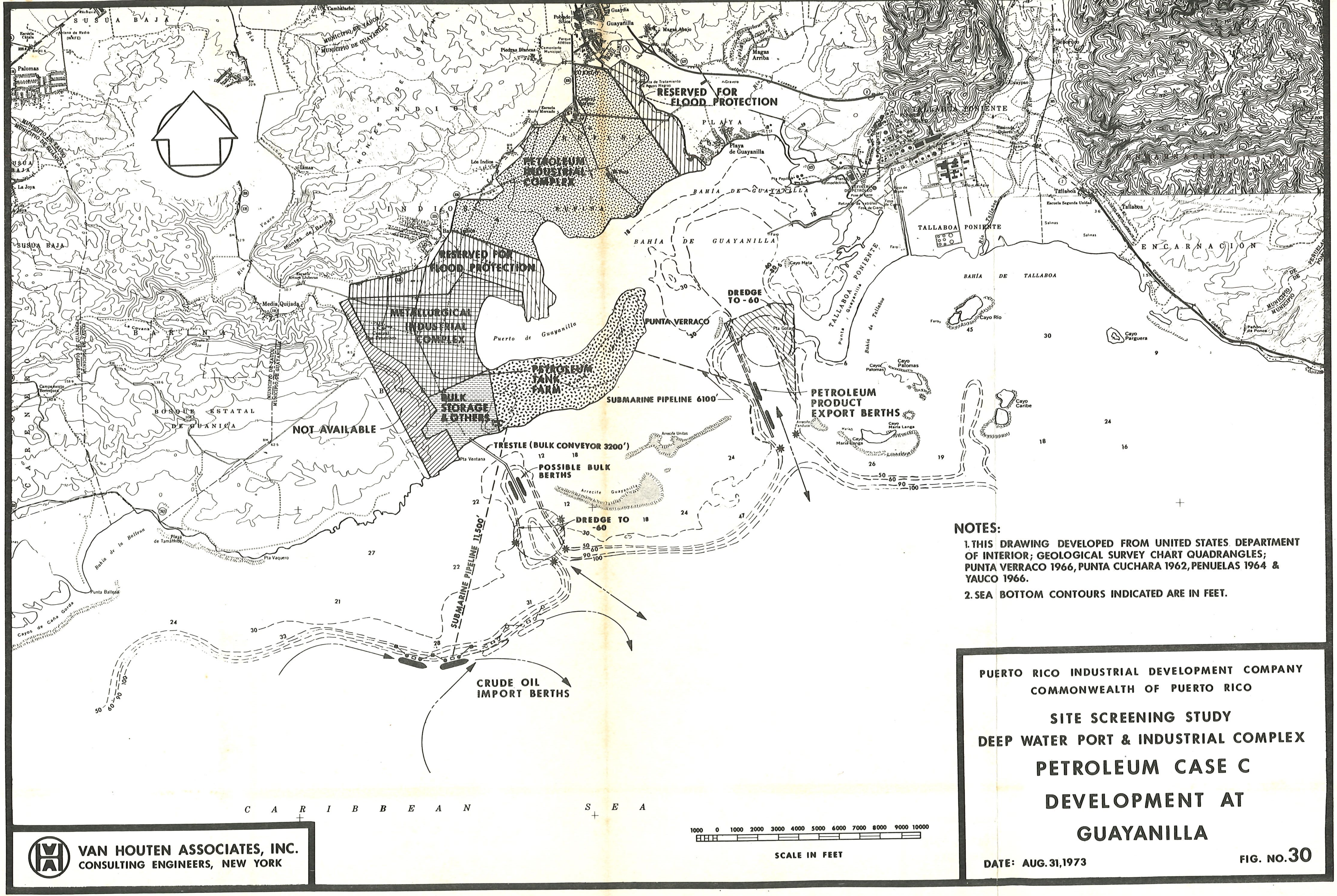
VAN HOUTEN ASSOCIATES, INC.
CONSULTING ENGINEERS, NEW YORK

PUERTO RICO INDUSTRIAL DEVELOPMENT COMPANY
COMMONWEALTH OF PUERTO RICO
SITE SCREENING STUDY
DEEP WATER PORT & INDUSTRIAL COMPLEX

PETROLEUM CASE C
DISTRIBUTION FROM
PUNTA CABULLON

DATE: AUG.31,1973

FIG.NO.29



NOTES:

1. THIS DRAWING DEVELOPED FROM UNITED STATES DEPARTMENT OF INTERIOR; GEOLOGICAL SURVEY CHART QUADRANGLES; PUNTA VERRACO 1966, PUNTA CUCHARA 1962, PENUELAS 1964 & YAUCO 1966.
2. SEA BOTTOM CONTOURS INDICATED ARE IN FEET.

PUERTO RICO INDUSTRIAL DEVELOPMENT COMPANY
COMMONWEALTH OF PUERTO RICO

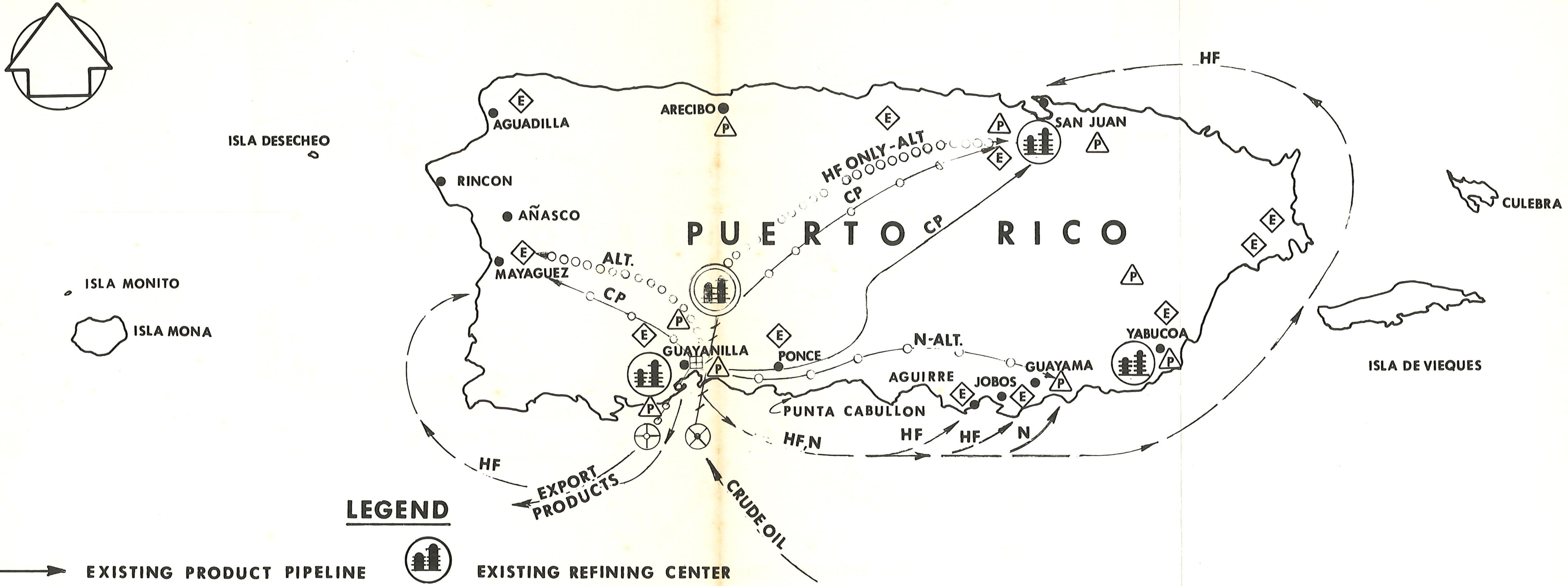
SITE SCREENING STUDY
DEEP WATER PORT & INDUSTRIAL COMPLEX

PETROLEUM CASE C
DEVELOPMENT AT
GUAYANILLA

DATE: AUG. 31, 1973

FIG. NO. 30

VAN HOUTEN ASSOCIATES, INC.
CONSULTING ENGINEERS, NEW YORK



LEGEND

——→	EXISTING PRODUCT PIPELINE
—o—o—o→	NEW PRODUCT PIPELINE
—/—/—/→	NEW CRUDE OIL PIPELINE
— — — —→	BARGE TANKER ROUTE
oooooooo→	TANK TRUCKAGE
◇E	ELECTRICAL POWER PLANT
△P	PETROCHEMICAL PLANT
◎	EXISTING REFINING CENTER
◎	NEW REFINING CENTER
●	CITY
⊕	NEW DEEP WATER PRODUCT TERMINAL
⊗	NEW DEEP WATER CRUDE OIL TERMINAL
⊞	NEW PRODUCT DISTRIBUTION CENTER
☒	NEW CRUDE OIL DISTRIBUTION CENTER
HF	HEAVY FUELS
N	UNFINISHED NAPHTHAS
CP	CONSUMER PRODUCTS
ALT.	ALTERNATE METHOD

0 5 10 15 20
SCALE IN NAUTICAL MILES

VAN HOUTEN ASSOCIATES, INC.
CONSULTING ENGINEERS, NEW YORK

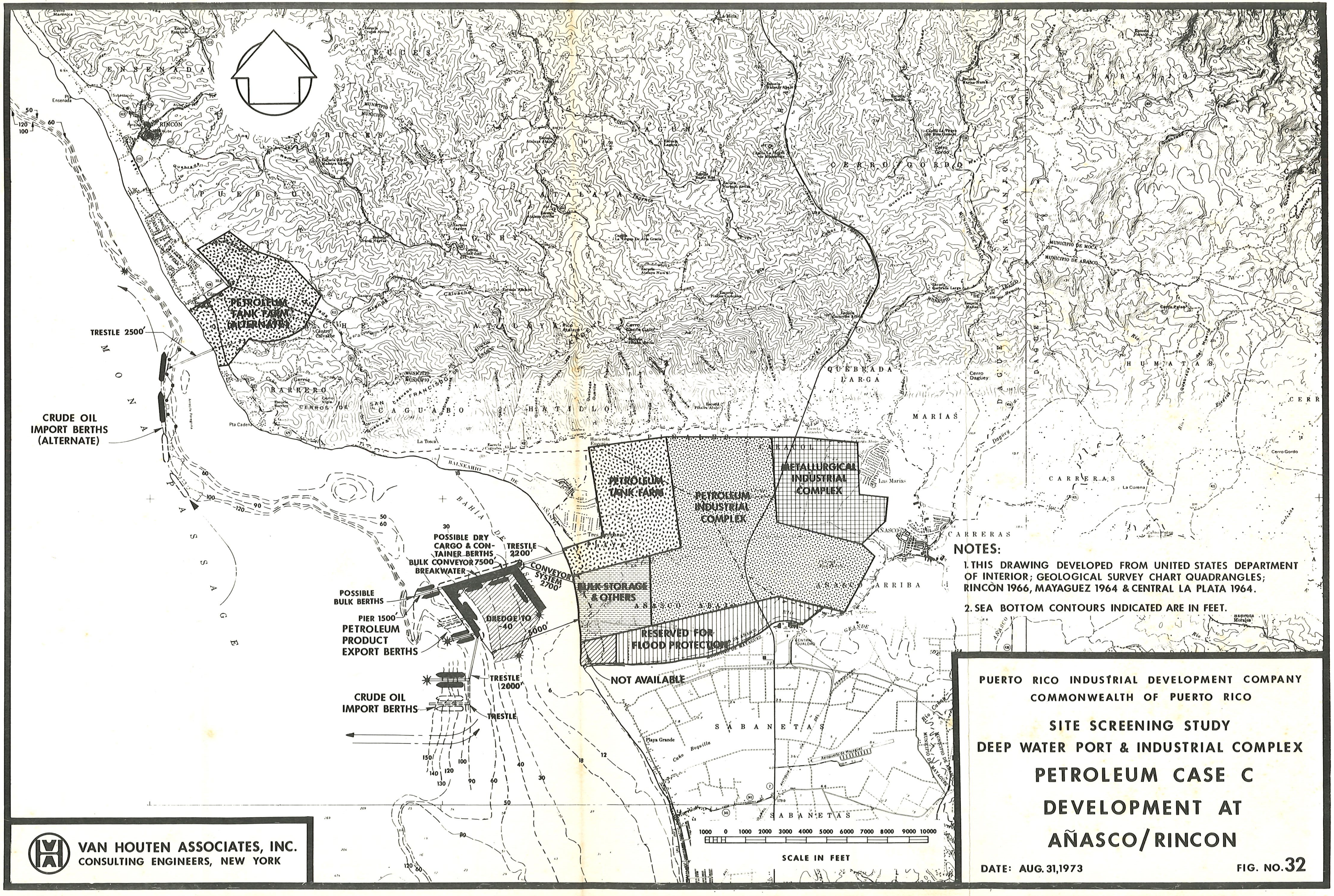
PUERTO RICO INDUSTRIAL DEVELOPMENT COMPANY
COMMONWEALTH OF PUERTO RICO

SITE SCREENING STUDY
DEEP WATER PORT & INDUSTRIAL COMPLEX

PETROLEUM CASE C
DISTRIBUTION FROM GUAYANILLA

DATE: AUG. 31, 1973

FIG. NO. 31



NOTES:

1. THIS DRAWING DEVELOPED FROM UNITED STATES DEPARTMENT OF INTERIOR; GEOLOGICAL SURVEY CHART QUADRANGLES; RINCÒN 1966, MAYAGUEZ 1964 & CENTRAL LA PLATA 1964.
2. SEA BOTTOM CONTOURS INDICATED ARE IN FEET.

PUERTO RICO INDUSTRIAL DEVELOPMENT COMPANY
COMMONWEALTH OF PUERTO RICO

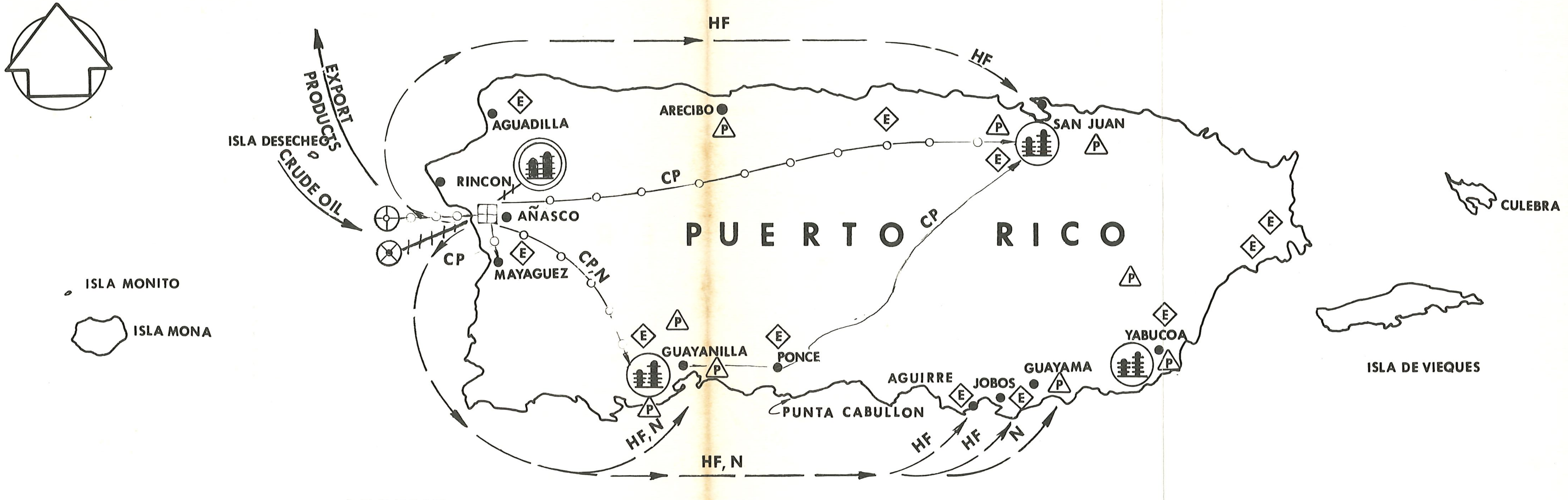
SITE SCREENING STUDY
DEEP WATER PORT & INDUSTRIAL COMPLEX

PETROLEUM CASE C
DEVELOPMENT AT
AÑASCO/RINCON

DATE: AUG. 31,1973

FIG. NO. 32

VAN HOUTEN ASSOCIATES, INC.
CONSULTING ENGINEERS, NEW YORK



LEGEND

⟶	EXISTING PRODUCT PIPELINE	◉	EXISTING REFINING CENTER
–o–o–o⟶	NEW PRODUCT PIPELINE	◎	NEW REFINING CENTER
–/–/–/⟶	NEW CRUDE OIL PIPELINE	●	CITY
— — —⟶	BARGE TANKER ROUTE	⊕	NEW DEEP WATER PRODUCT TERMINAL
oooooooo⟶	TANK TRUCKAGE	⊗	NEW DEEP WATER CRUDE OIL TERMINAL
E	ELECTRICAL POWER PLANT	⊞	NEW PRODUCT DISTRIBUTION CENTER
P	PETROCHEMICAL PLANT	⊠	NEW CRUDE OIL DISTRIBUTION CENTER
		HF	HEAVY FUELS
		N	UNFINISHED NAPHTHAS
		CP	CONSUMER PRODUCTS
		ALT	ALTERNATE METHOD

0 5 10 15 20

SCALE IN NAUTICAL MILES

VAN HOUTEN ASSOCIATES, INC.
CONSULTING ENGINEERS, NEW YORK

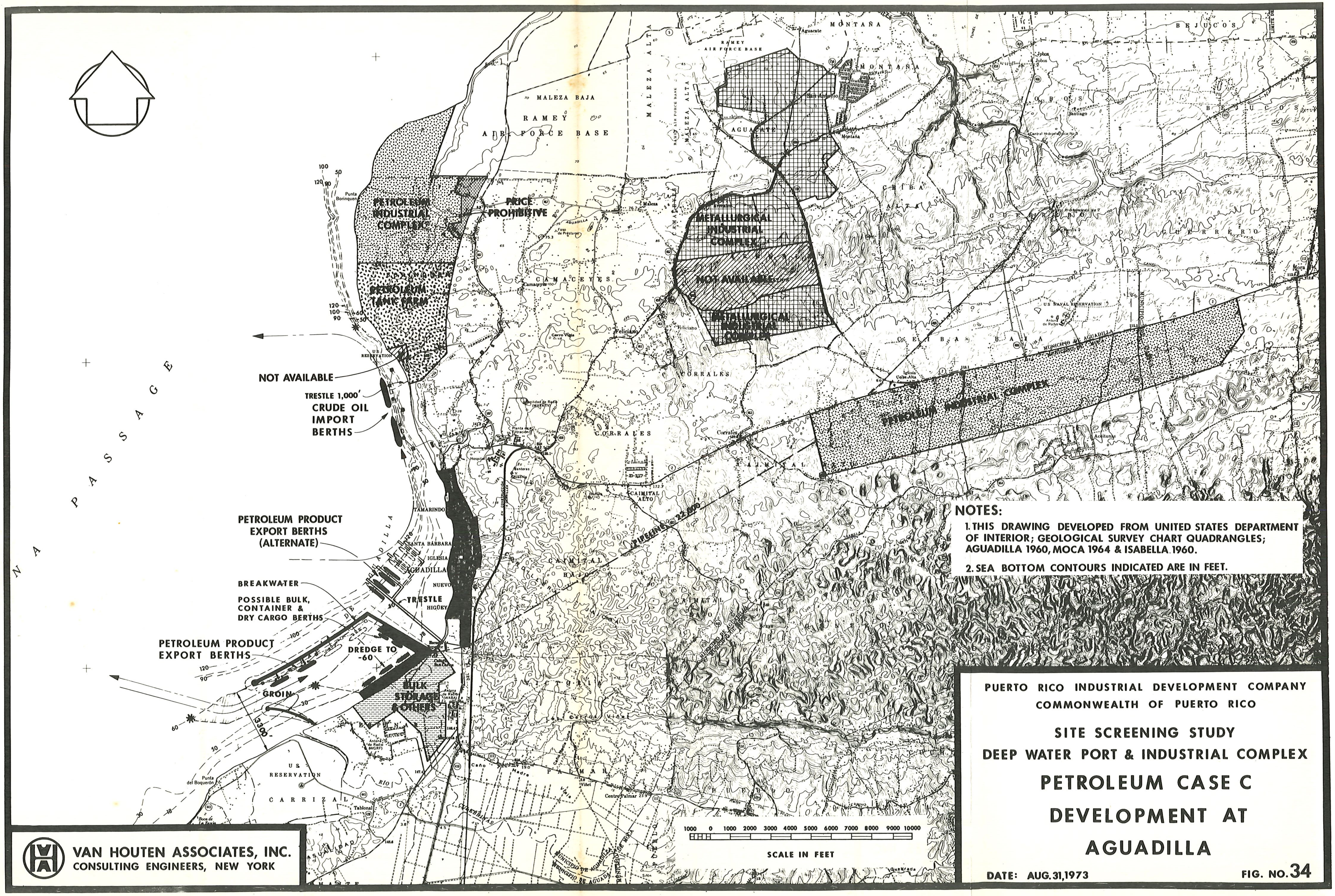
PUERTO RICO INDUSTRIAL DEVELOPMENT COMPANY
COMMONWEALTH OF PUERTO RICO
SITE SCREENING STUDY
DEEP WATER PORT & INDUSTRIAL COMPLEX

PETROLEUM CASE C

DISTRIBUTION FROM AÑASCO/RINCON

DATE: AUG.31,1973

FIG. NO. 33



NOTES:

1. THIS DRAWING DEVELOPED FROM UNITED STATES DEPARTMENT OF INTERIOR; GEOLOGICAL SURVEY CHART QUADRANGLES; AGUADILLA 1960, MOCA 1964 & ISABELLA 1960.
2. SEA BOTTOM CONTOURS INDICATED ARE IN FEET.

PUERTO RICO INDUSTRIAL DEVELOPMENT COMPANY
COMMONWEALTH OF PUERTO RICO

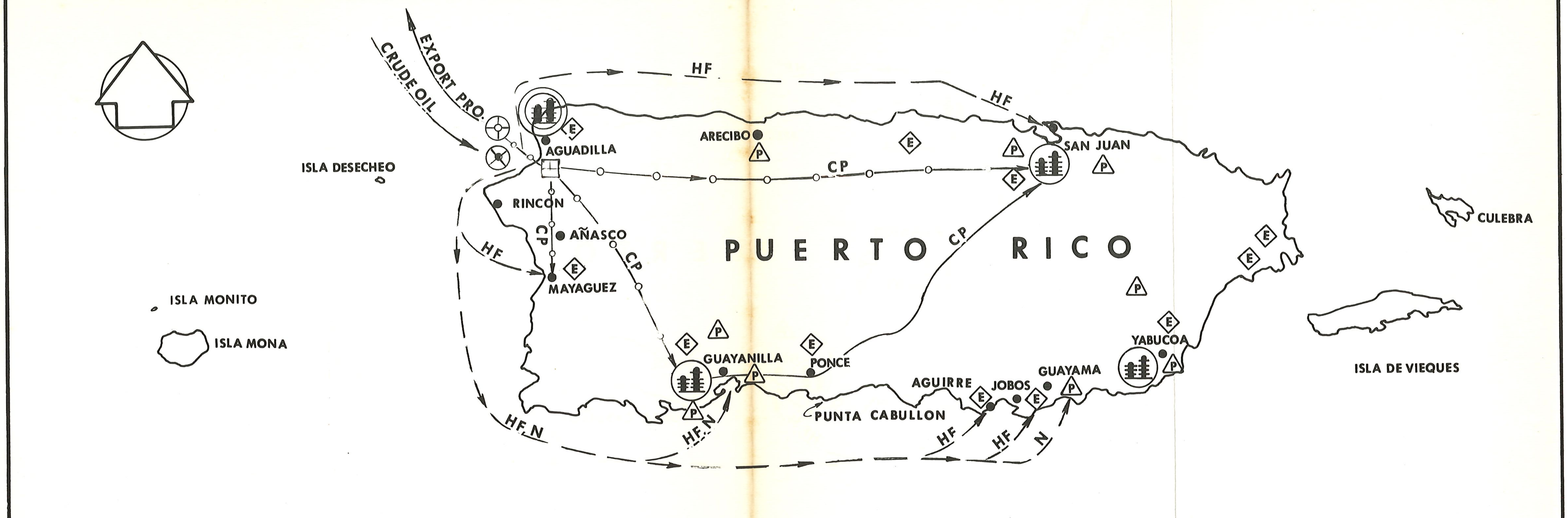
SITE SCREENING STUDY
DEEP WATER PORT & INDUSTRIAL COMPLEX

PETROLEUM CASE C
DEVELOPMENT AT
AGUADILLA

DATE: AUG. 31, 1973

FIG. NO. 34

VAN HOUTEN ASSOCIATES, INC.
CONSULTING ENGINEERS, NEW YORK



LEGEND

⟶	EXISTING PRODUCT PIPELINE
—○—○—○⟶	NEW PRODUCT PIPELINE
○○○○○○○○○⟶	TANK TRUCKAGE
— — —⟶	BARGE TANKER ROUTE
●	CITY
HF	HEAVY FUELS
N	UNFINISHED NAPHTHAS
◈	ELECTRICAL POWER PLANT
△	PETROCHEMICAL PLANT
◉	EXISTING REFINING CENTER
⊕	NEW DEEP WATER PRODUCT TERMINAL
⊗	NEW DEEP WATER CRUDE OIL TERMINAL
⊞	NEW PRODUCT DISTRIBUTION CENTER
⊠	NEW CRUDE OIL DISTRIBUTION CENTER
CP	CONSUMER PRODUCTS
ALT.	ALTERNATE METHOD

0 5 10 15 20
SCALE IN NAUTICAL MILES

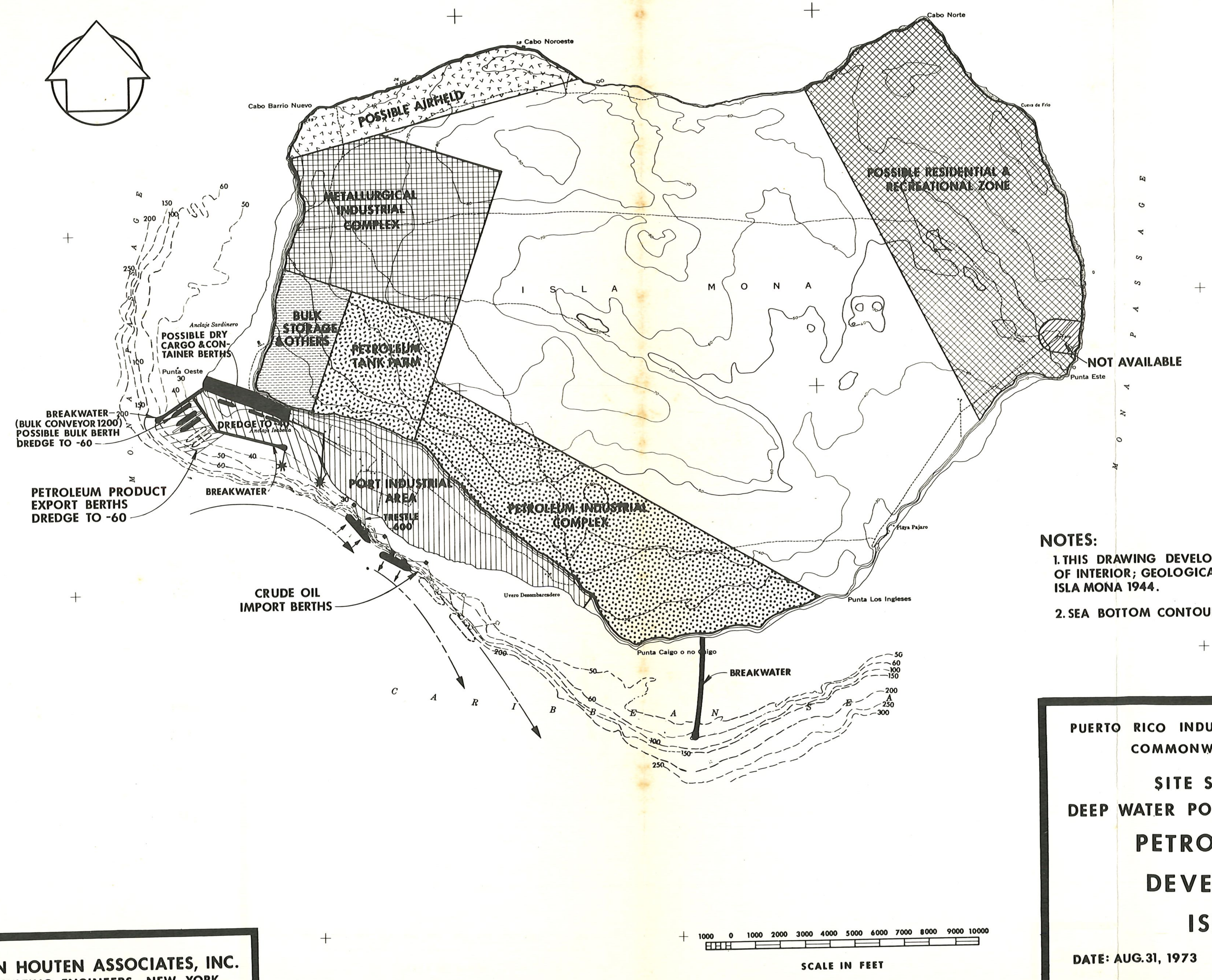
VAN HOUTEN ASSOCIATES, INC.
CONSULTING ENGINEERS, NEW YORK

PUERTO RICO INDUSTRIAL DEVELOPMENT COMPANY
COMMONWEALTH OF PUERTO RICO

SITE SCREENING STUDY
DEEP WATER PORT INDUSTRIAL COMPLEX
PETROLEUM CASE C
DISTRIBUTION FROM AGUADILLA

DATE: AUG. 31,1973

FIG. NO. 35



NOTES:

1. THIS DRAWING DEVELOPED FROM UNITED STATES DEPARTMENT OF INTERIOR; GEOLOGICAL SURVEY CHART QUADRANGLES; ISLA MONA 1944.
2. SEA BOTTOM CONTOURS INDICATED ARE IN FEET.

VAN HOUTEN ASSOCIATES, INC.
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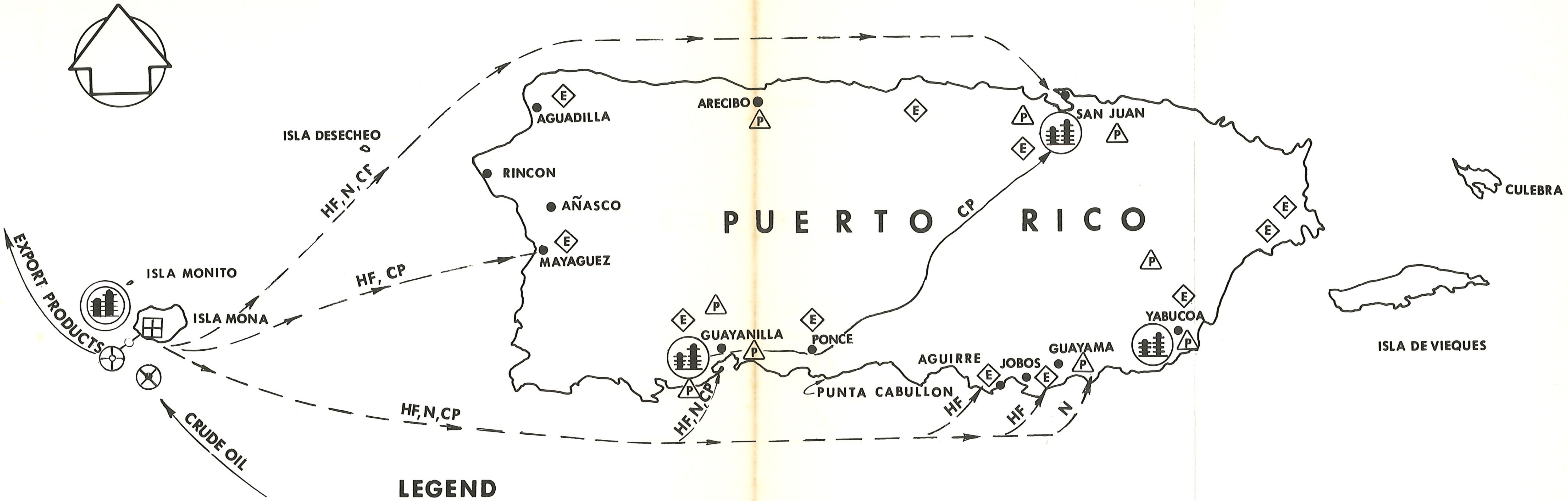
PUERTO RICO INDUSTRIAL DEVELOPMENT COMPANY
COMMONWEALTH OF PUERTO RICO

SITE SCREENING STUDY
DEEP WATER PORT & INDUSTRIAL COMPLEX

PETROLEUM CASE C
DEVELOPMENT AT
ISLA MONA

DATE: AUG. 31, 1973

FIG. NO. 36



LEGEND

———→	EXISTING PRODUCT PIPELINE
—o—o—o→	NEW PRODUCT PIPELINE
—/—/—/→	NEW CRUDE OIL PIPELINE
— — — →	BARGE TANKER ROUTE
oooooooo→	TANK TRUCKAGE
E	ELECTRICAL POWER PLANT
P	PETROCHEMICAL PLANT
◯	EXISTING REFINING CENTER
◎	NEW REFINING CENTER
●	CITY
⊕	NEW DEEP WATER PRODUCT TERMINAL
⊗	NEW DEEP WATER CRUDE OIL TERMINAL
⊞	NEW PRODUCT DISTRIBUTION CENTER
⊠	NEW CRUDE OIL DISTRIBUTION CENTER
HF	HEAVY FUELS
N	UNFINISHED NAPHTHAS
CP	CONSUMER PRODUCTS
ALT.	ALTERNATE METHOD

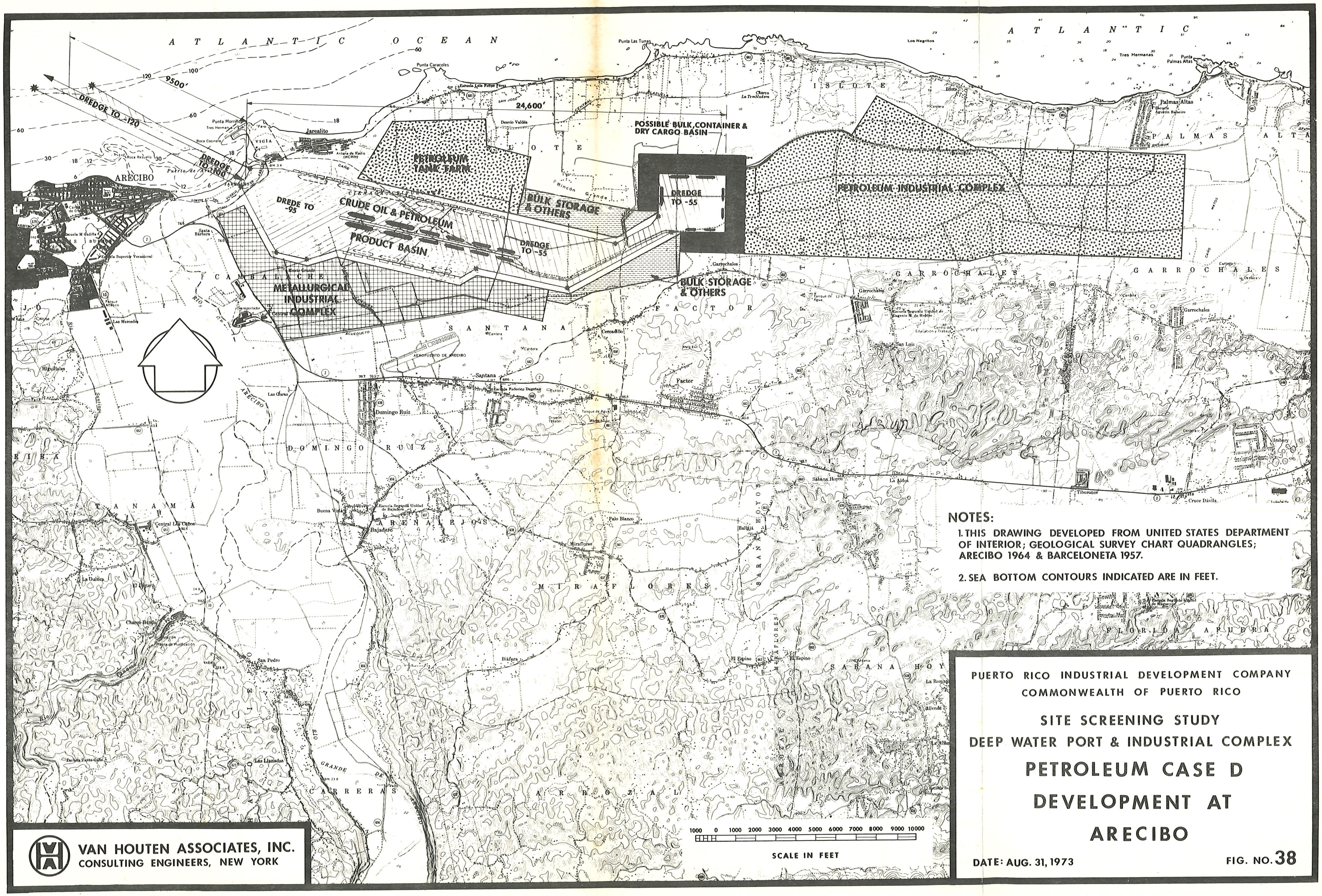
0 5 10 15 20
SCALE IN NAUTICAL MILES

PUERTO RICO INDUSTRIAL DEVELOPMENT COMPANY
COMMONWEALTH OF PUERTO RICO
SITE SCREENING STUDY
DEEP WATER PORT & INDUSTRIAL COMPLEX

PETROLEUM CASE C
DISTRIBUTION FROM ISLA MONA

DATE: AUG. 31, 1973 FIG. NO. 37

VAN HOUTEN ASSOCIATES, INC.
CONSULTING ENGINEERS, NEW YORK



NOTES:

1. THIS DRAWING DEVELOPED FROM UNITED STATES DEPARTMENT OF INTERIOR; GEOLOGICAL SURVEY CHART QUADRANGLES; ARECIBO 1964 & BARCELONETA 1957.
2. SEA BOTTOM CONTOURS INDICATED ARE IN FEET.

PUERTO RICO INDUSTRIAL DEVELOPMENT COMPANY
COMMONWEALTH OF PUERTO RICO

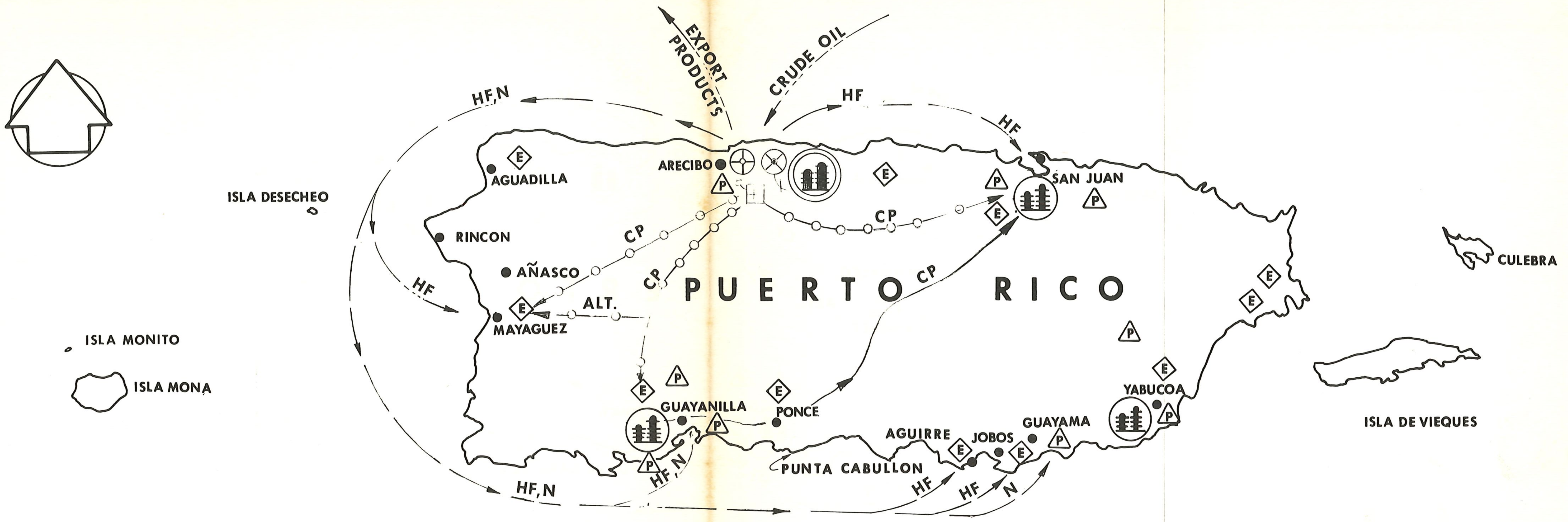
SITE SCREENING STUDY
DEEP WATER PORT & INDUSTRIAL COMPLEX

PETROLEUM CASE D DEVELOPMENT AT ARECIBO

DATE: AUG. 31, 1973

FIG. NO. 38

VAN HOUTEN ASSOCIATES, INC.
CONSULTING ENGINEERS, NEW YORK



LEGEND

——→	EXISTING PRODUCT PIPELINE
–o–o–o→	NEW PRODUCT PIPELINE
–/–/–/→	NEW CRUDE OIL PIPELINE
– – – →	BARGE TANKER ROUTE
oooooooo→	TANK TRUCKAGE
◇E	ELECTRICAL POWER PLANT
△P	PETROCHEMICAL PLANT
	EXISTING REFINING CENTER
	NEW REFINING CENTER
●	CITY
⊕	NEW DEEP WATER PRODUCT TERMINAL
⊗	NEW DEEP WATER CRUDE OIL TERMINAL
⊞	NEW PRODUCT DISTRIBUTION CENTER
☒	NEW CRUDE OIL DISTRIBUTION CENTER
HF	HEAVY FUELS
N	UNFINISHED NAPHTHAS
CP	CONSUMER PRODUCTS
ALT.	ALTERNATE METHOD

0 5 10 15 20
SCALE IN NAUTICAL MILES

VAN HOUTEN ASSOCIATES, INC.
CONSULTING ENGINEERS, NEW YORK

PUERTO RICO INDUSTRIAL DEVELOPMENT COMPANY
COMMONWEALTH OF PUERTO RICO

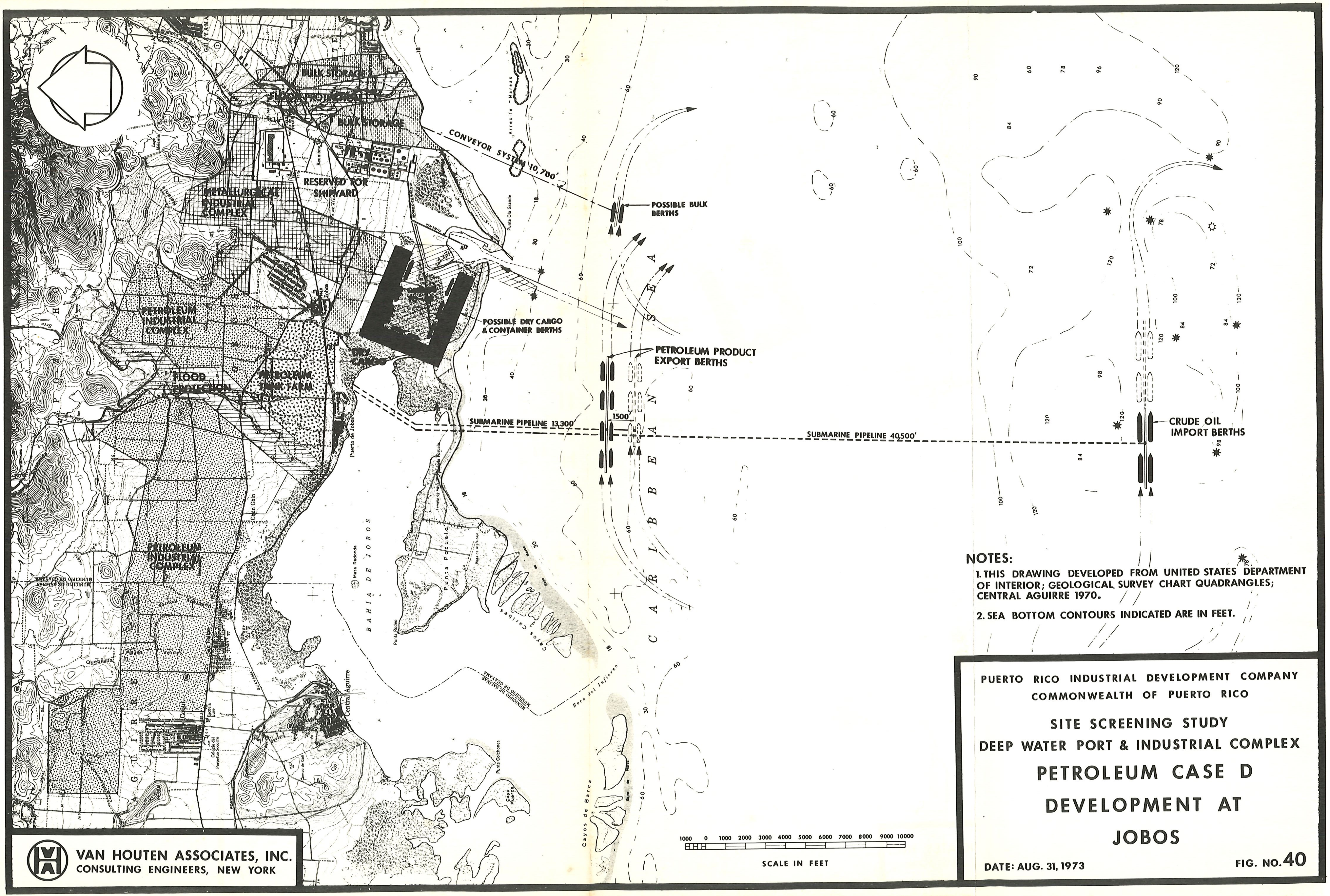
SITE SCREENING STUDY
DEEP WATER PORT & INDUSTRIAL COMPLEX

PETROLEUM CASE D

DISTRIBUTION FROM ARECIBO

DATE: AUG. 31, 1973

FIG. NO. 39



NOTES:

1. THIS DRAWING DEVELOPED FROM UNITED STATES DEPARTMENT OF INTERIOR; GEOLOGICAL SURVEY CHART QUADRANGLES; CENTRAL AGUIRRE 1970.
2. SEA BOTTOM CONTOURS INDICATED ARE IN FEET.

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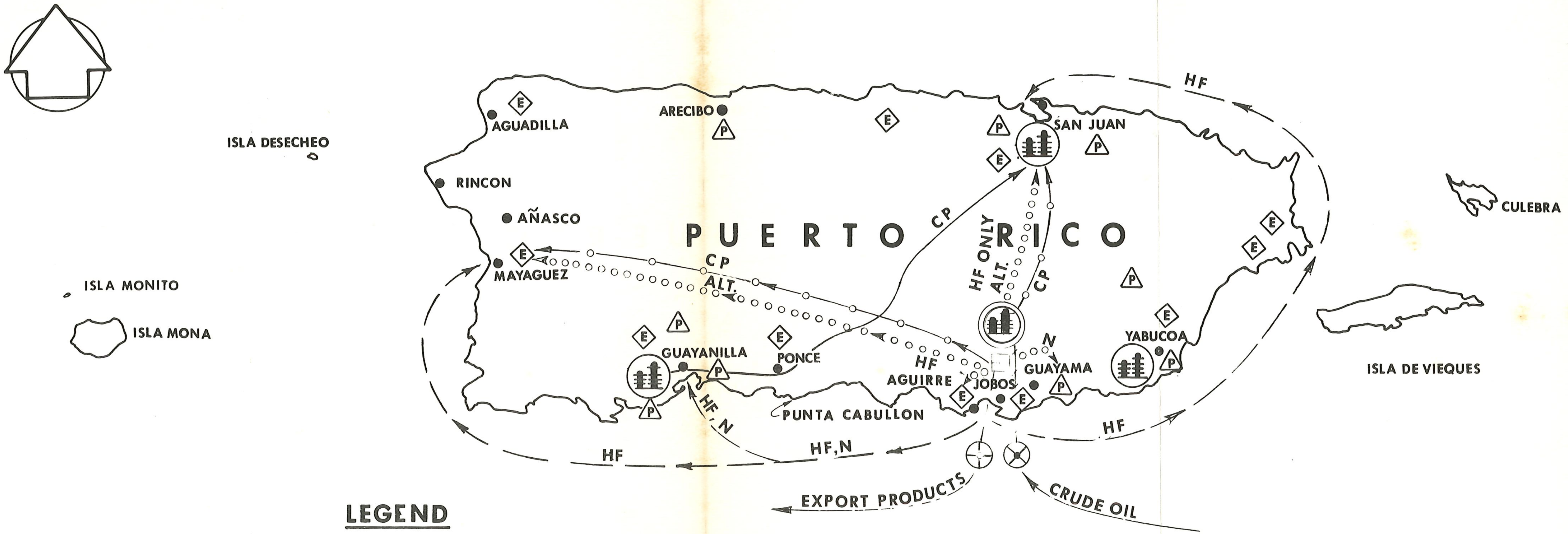
PUERTO RICO INDUSTRIAL DEVELOPMENT COMPANY
COMMONWEALTH OF PUERTO RICO

SITE SCREENING STUDY
DEEP WATER PORT & INDUSTRIAL COMPLEX

PETROLEUM CASE D
DEVELOPMENT AT
JOBOS

DATE: AUG. 31, 1973

FIG. NO. 40



LEGEND

——→	EXISTING PRODUCT PIPELINE
—o—o—o→	NEW PRODUCT PIPELINE
—/—/—/→	NEW CRUDE OIL PIPELINE
— — — —→	BARGE TANKER ROUTE
oooooooo→	TANK TRUCKAGE
◇E	ELECTRICAL POWER PLANT
△P	PETROCHEMICAL PLANT
◎	EXISTING REFINING CENTER
◎	NEW REFINING CENTER
●	CITY
⊕	NEW DEEP WATER PRODUCT TERMINAL
⊗	NEW DEEP WATER CRUDE OIL TERMINAL
⊞	NEW PRODUCT DISTRIBUTION CENTER
☒	NEW CRUDE OIL DISTRIBUTION CENTER
HF	HEAVY FUELS
N	UNFINISHED NAPHTHAS
CP	CONSUMER PRODUCTS
ALT.	ALTERNATE METHOD

0 5 10 15 20
SCALE IN NAUTICAL MILES

VAN HOUTEN ASSOCIATES, INC.
CONSULTING ENGINEERS, NEW YORK

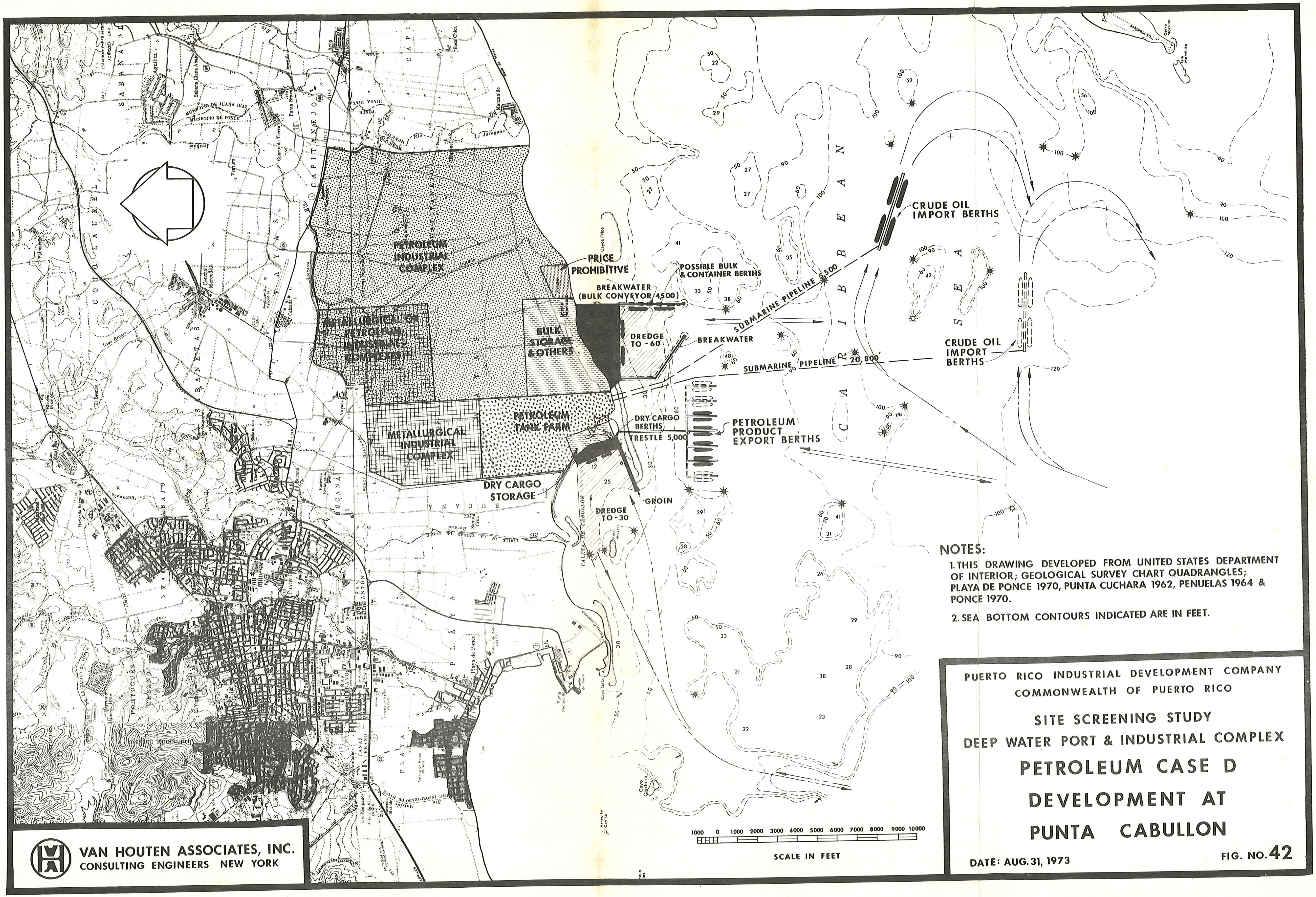
PUERTO RICO INDUSTRIAL DEVELOPMENT COMPANY
COMMONWEALTH OF PUERTO RICO

SITE SCREENING STUDY
DEEP WATER PORT & INDUSTRIAL COMPLEX

PETROLEUM CASE D
DISTRIBUTION FROM JOBOS

DATE: AUG. 31, 1973

FIG. NO. 41



NOTES:

1. THIS DRAWING DEVELOPED FROM UNITED STATES DEPARTMENT OF INTERIOR; GEOLOGICAL SURVEY CHART QUADRANGLES; PLAYA DE PONCE 1970, PUNTA CUCHARA 1962, PENUELAS 1964 & PONCE 1970.
2. SEA BOTTOM CONTOURS INDICATED ARE IN FEET.

PUERTO RICO INDUSTRIAL DEVELOPMENT COMPANY
COMMONWEALTH OF PUERTO RICO

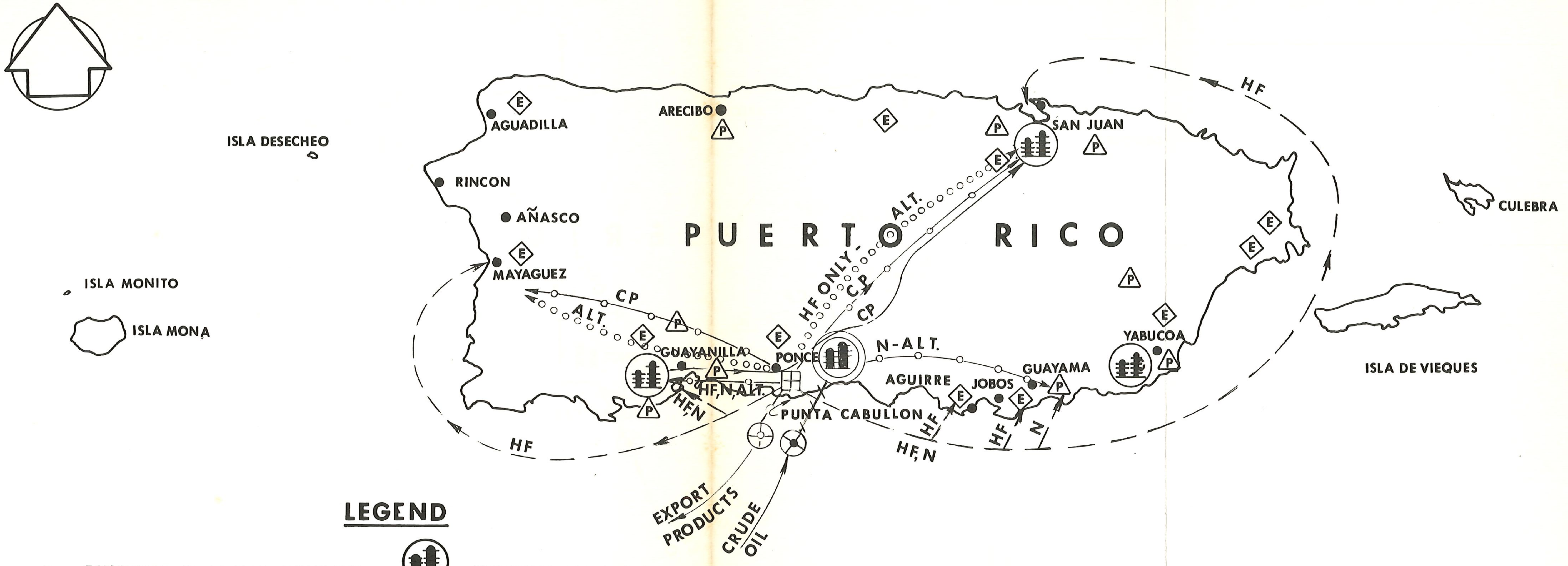
SITE SCREENING STUDY
DEEP WATER PORT & INDUSTRIAL COMPLEX

PETROLEUM CASE D
DEVELOPMENT AT
PUNTA CABULLON

DATE: AUG. 31, 1973

FIG. NO. 42

VAN HOUTEN ASSOCIATES, INC.
CONSULTING ENGINEERS NEW YORK



LEGEND

→	EXISTING PRODUCT PIPELINE
—o—o—o→	NEW PRODUCT PIPELINE
—/—/—/→	NEW CRUDE OIL PIPELINE
— — — →	BARGE TANKER ROUTE
oooooooo→	TANK TRUCKAGE
◇E	ELECTRICAL POWER PLANT
△P	PETROCHEMICAL PLANT
◉	EXISTING REFINING CENTER
◎	NEW REFINING CENTER
●	CITY
⊕	NEW DEEP WATER PRODUCT TERMINAL
⊗	NEW DEEP WATER CRUDE OIL TERMINAL
⊞	NEW PRODUCT DISTRIBUTION CENTER
⊠	NEW CRUDE OIL DISTRIBUTION CENTER
HF	HEAVY FUELS
N	UNFINISHED NAPHTHAS
CP	CONSUMER PRODUCTS
ALT.	ALTERNATE METHOD

0 5 10 15 20
SCALE IN NAUTICAL MILES

VAN HOUTEN ASSOCIATES, INC.
CONSULTING ENGINEERS, NEW YORK

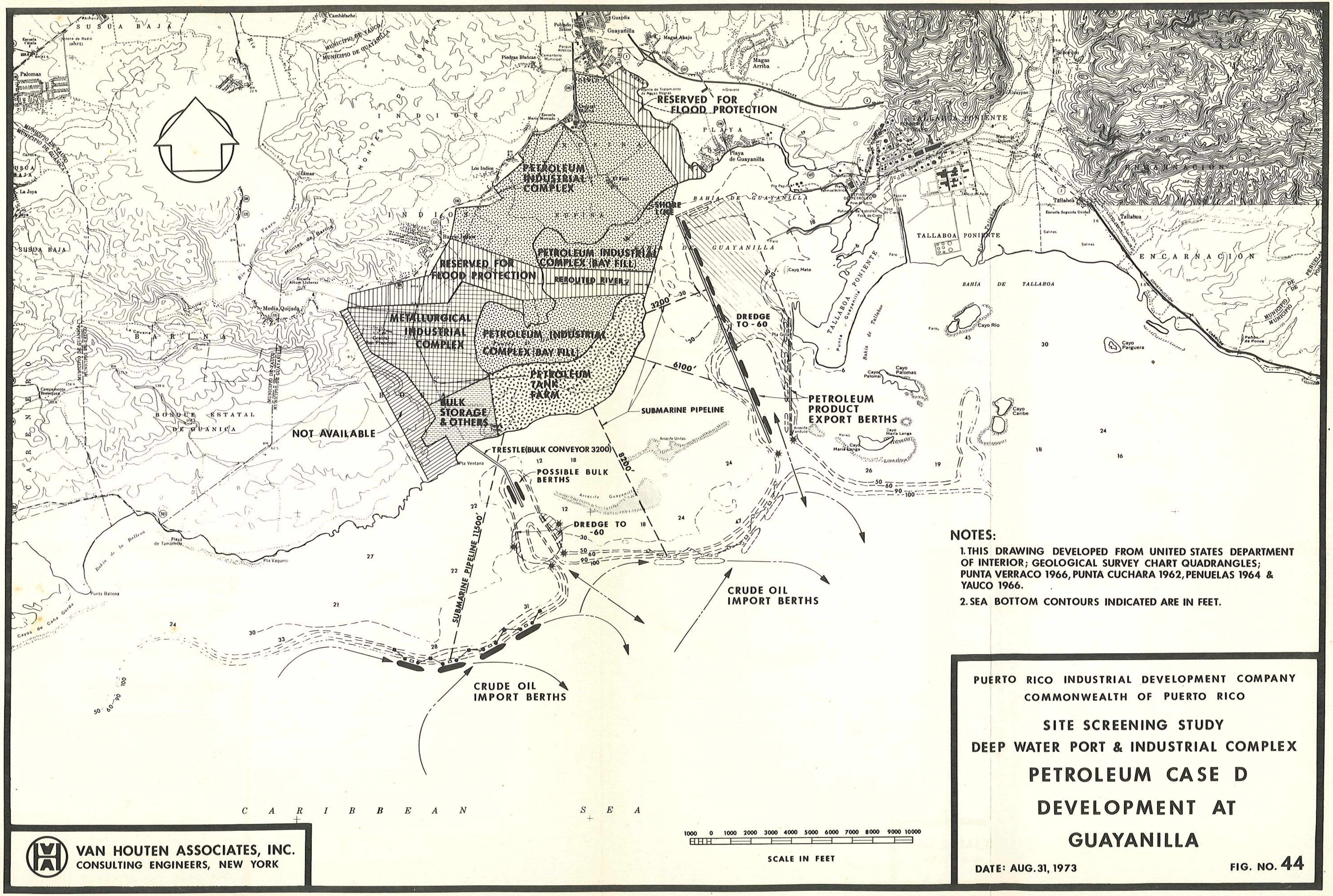
PUERTO RICO INDUSTRIAL DEVELOPMENT COMPANY
COMMONWEALTH OF PUERTO RICO

SITE SCREENING STUDY
DEEP WATER PORT & INDUSTRIAL COMPLEX

PETROLEUM CASE D
DISTRIBUTION FROM
PUNTA CABULLON

DATE: AUG. 31, 1973

FIG. NO. 43



NOTES:

1. THIS DRAWING DEVELOPED FROM UNITED STATES DEPARTMENT OF INTERIOR; GEOLOGICAL SURVEY CHART QUADRANGLES; PUNTA VERRACO 1966, PUNTA CUCHARA 1962, PENUELAS 1964 & YAUCO 1966.
2. SEA BOTTOM CONTOURS INDICATED ARE IN FEET.

PUERTO RICO INDUSTRIAL DEVELOPMENT COMPANY
COMMONWEALTH OF PUERTO RICO

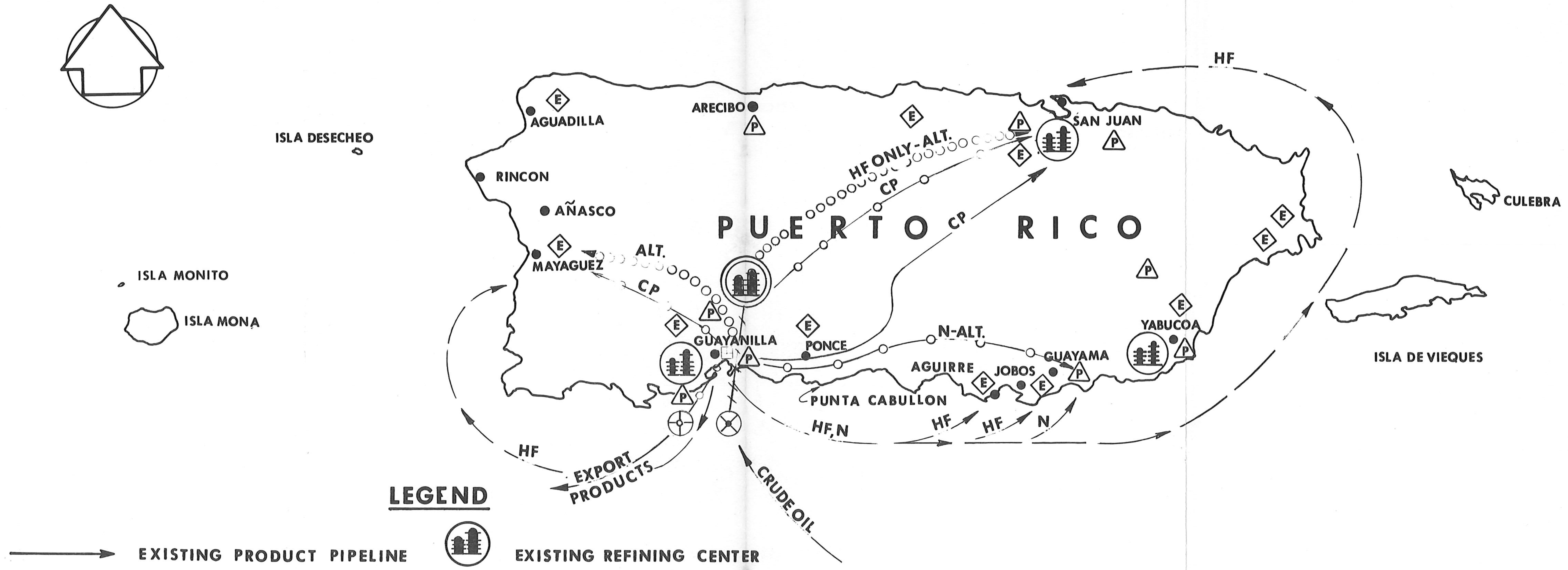
SITE SCREENING STUDY
DEEP WATER PORT & INDUSTRIAL COMPLEX

PETROLEUM CASE D
DEVELOPMENT AT
GUAYANILLA

DATE: AUG. 31, 1973

FIG. NO. 44

VAN HOUTEN ASSOCIATES, INC.
CONSULTING ENGINEERS, NEW YORK



LEGEND

——→	EXISTING PRODUCT PIPELINE
—o—o—o→	NEW PRODUCT PIPELINE
—/—/—/→	NEW CRUDE OIL PIPELINE
— — — →	BARGE TANKER ROUTE
oooooooo>	TANK TRUCKAGE
◈ E	ELECTRICAL POWER PLANT
△ P	PETROCHEMICAL PLANT
	EXISTING REFINING CENTER
	NEW REFINING CENTER
●	CITY
⊕	NEW DEEP WATER PRODUCT TERMINAL
⊗	NEW DEEP WATER CRUDE OIL TERMINAL
⊞	NEW PRODUCT DISTRIBUTION CENTER
⊠	NEW CRUDE OIL DISTRIBUTION CENTER
HF	HEAVY FUELS
N	UNFINISHED NAPHTHAS
CP	CONSUMER PRODUCTS
ALT.	ALTERNATE METHOD

0 5 10 15 20
SCALE IN NAUTICAL MILES

VAN HOUTEN ASSOCIATES, INC.
CONSULTING ENGINEERS, NEW YORK

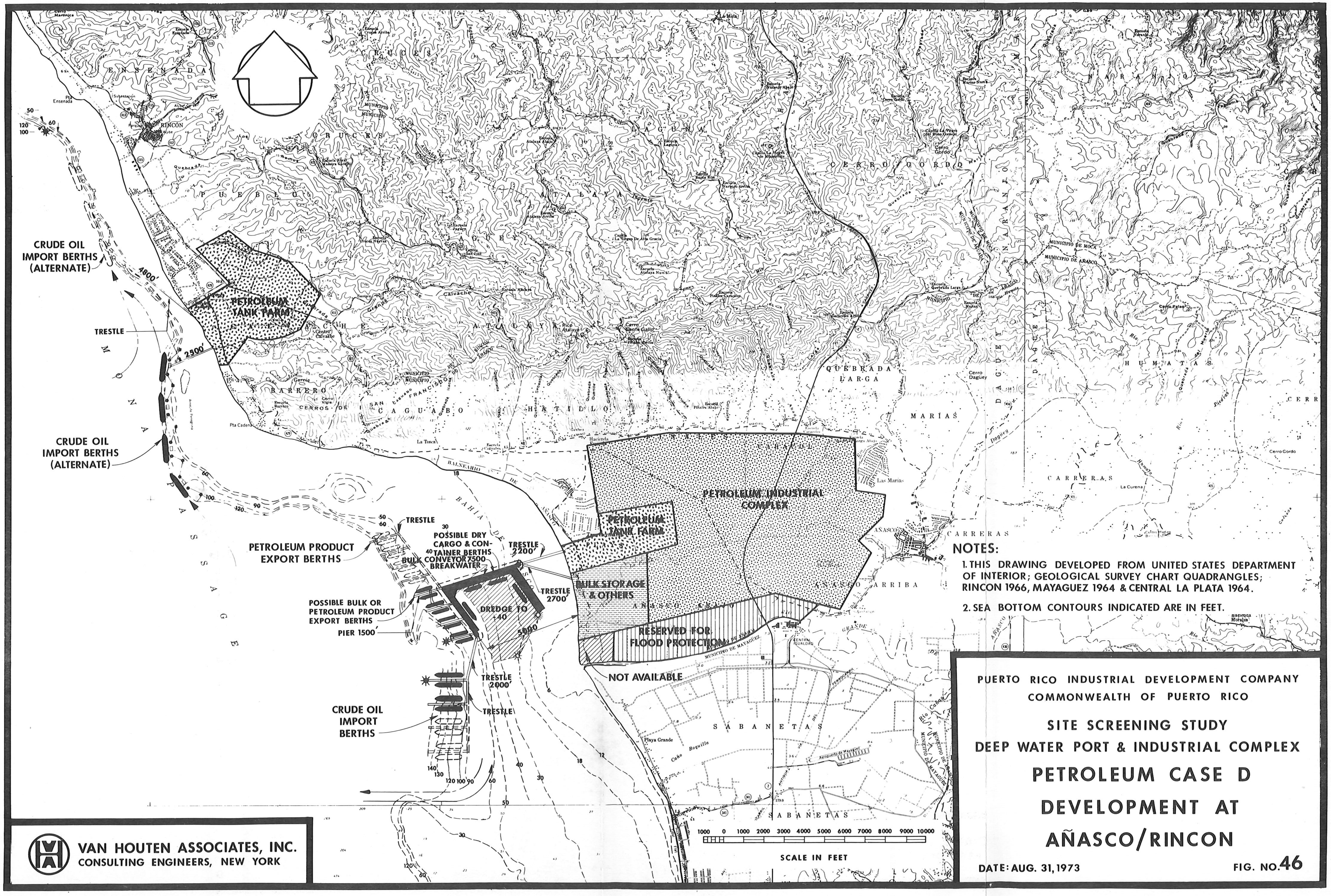
PUERTO RICO INDUSTRIAL DEVELOPMENT COMPANY
COMMONWEALTH OF PUERTO RICO

SITE SCREENING STUDY
DEEP WATER PORT & INDUSTRIAL COMPLEX

PETROLEUM CASE D
DISTRIBUTION FROM GUAYANILLA

DATE: AUG. 31 ,1973

FIG. NO. 45



NOTES:

1. THIS DRAWING DEVELOPED FROM UNITED STATES DEPARTMENT OF INTERIOR; GEOLOGICAL SURVEY CHART QUADRANGLES; RINCON 1966, MAYAGUEZ 1964 & CENTRAL LA PLATA 1964.
2. SEA BOTTOM CONTOURS INDICATED ARE IN FEET.

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CONSULTING ENGINEERS, NEW YORK

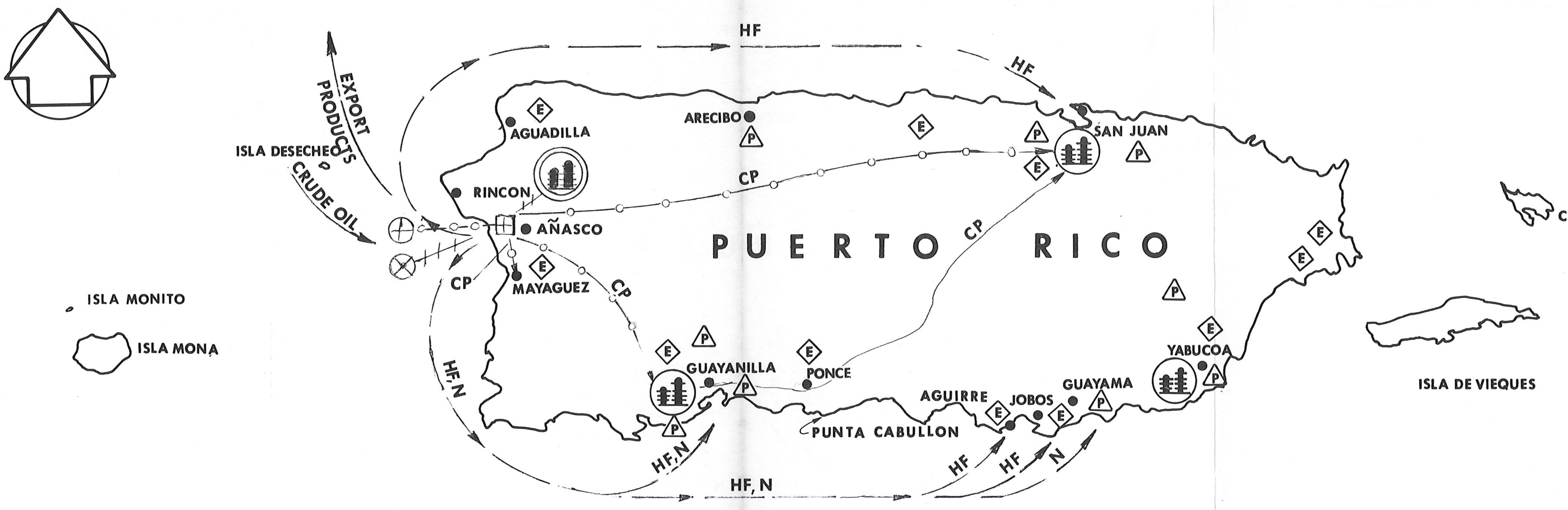
PUERTO RICO INDUSTRIAL DEVELOPMENT COMPANY
COMMONWEALTH OF PUERTO RICO

SITE SCREENING STUDY
DEEP WATER PORT & INDUSTRIAL COMPLEX

PETROLEUM CASE D DEVELOPMENT AT AÑASCO/RINCON

DATE: AUG. 31, 1973

FIG. NO. 46



LEGEND

——→	EXISTING PRODUCT PIPELINE
—○—○—○→	NEW PRODUCT PIPELINE
—/—/—/→	NEW CRUDE OIL PIPELINE
— — —→	BARGE TANKER ROUTE
○○○○○○○○→	TANK TRUCKAGE
◈E	ELECTRICAL POWER PLANT
△P	PETROCHEMICAL PLANT
◉	EXISTING REFINING CENTER
◎	NEW REFINING CENTER
●	CITY
⊕	NEW DEEP WATER PRODUCT TERMINAL
⊗	NEW DEEP WATER CRUDE OIL TERMINAL
⊞	NEW PRODUCT DISTRIBUTION CENTER
⊠	NEW CRUDE OIL DISTRIBUTION CENTER
HF	HEAVY FUELS
N	UNFINISHED NAPHTHAS
CP	CONSUMER PRODUCTS
ALT.	ALTERNATE METHOD

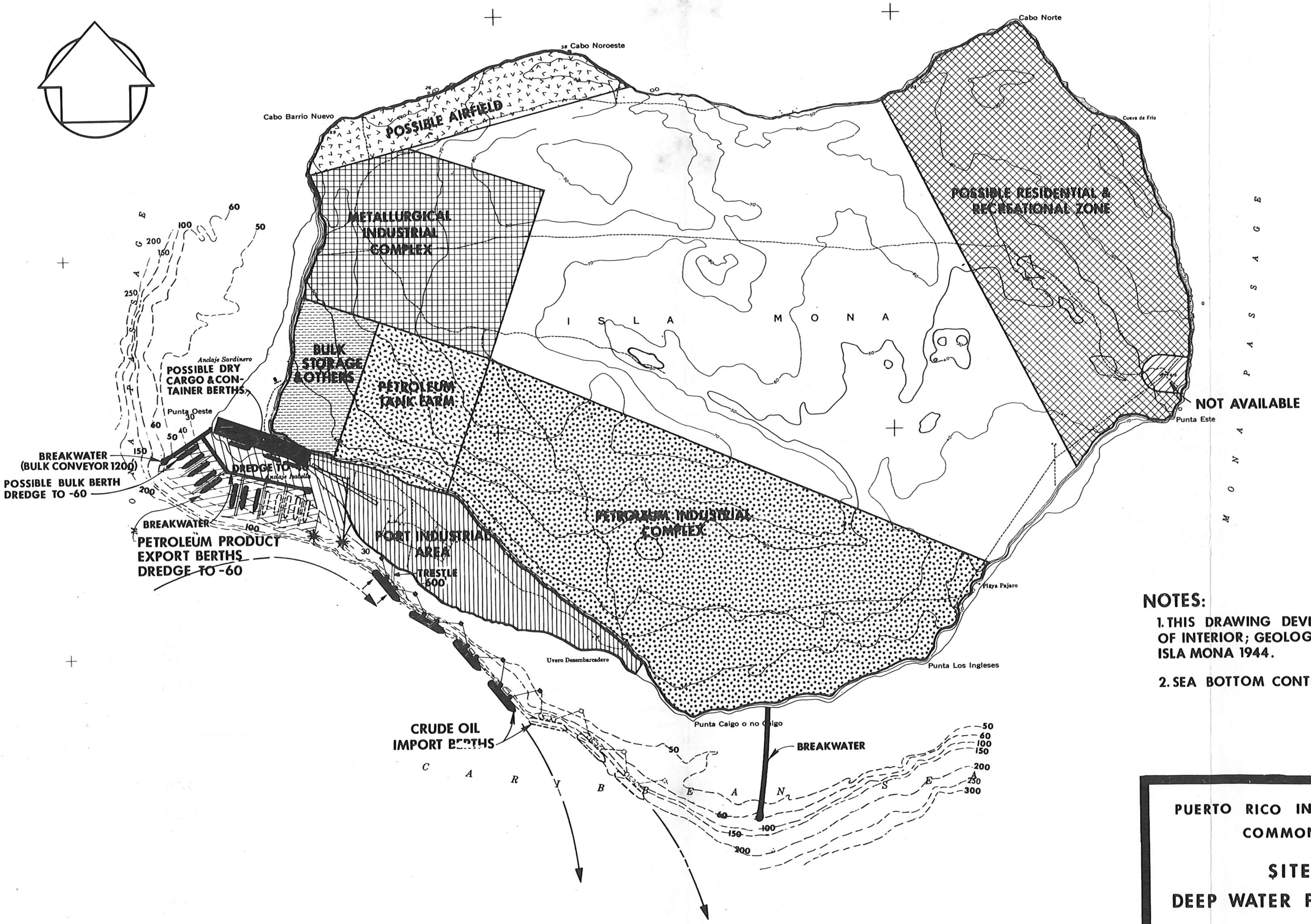
VAN HOUTEN ASSOCIATES, INC.
CONSULTING ENGINEERS, NEW YORK

PUERTO RICO INDUSTRIAL DEVELOPMENT COMPANY
COMMONWEALTH OF PUERTO RICO

SITE SCREENING STUDY
DEEP WATER PORT & INDUSTRIAL COMPLEX
PETROLEUM CASE D
DISTRIBUTION FROM AÑASCO/RINCON

DATE: AUG. 31, 1973

FIG. NO. 47



NOTES:

1. THIS DRAWING DEVELOPED FROM UNITED STATES DEPARTMENT OF INTERIOR; GEOLOGICAL SURVEY CHART QUADRANGLES; ISLA MONA 1944.
2. SEA BOTTOM CONTOURS INDICATED ARE IN FEET.

1000 0 1000 2000 3000 4000 5000 6000 7000 8000 9000 10000

SCALE IN FEET

PUERTO RICO INDUSTRIAL DEVELOPMENT COMPANY
COMMONWEALTH OF PUERTO RICO

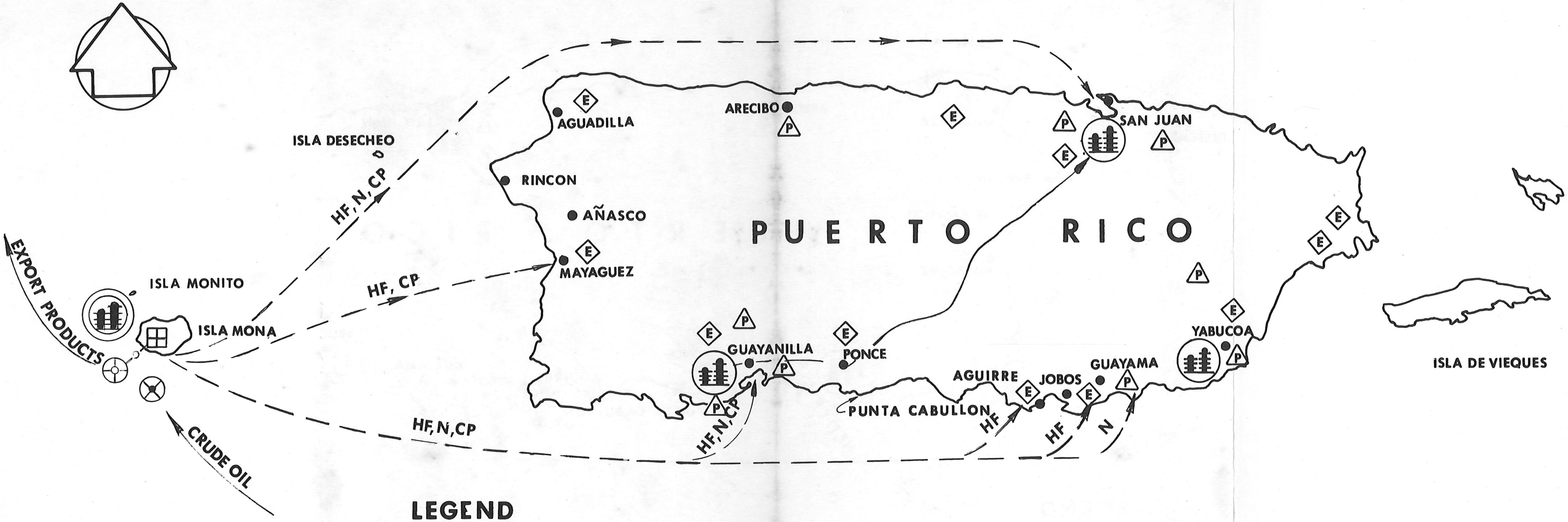
SITE SCREENING STUDY
DEEP WATER PORT & INDUSTRIAL COMPLEX

PETROLEUM CASE D
DEVELOPMENT AT
ISLA MONA

DATE: AUG. 31, 1973

FIG. NO. 48

VAN HOUTEN ASSOCIATES, INC.
CONSULTING ENGINEERS, NEW YORK



LEGEND

——→	EXISTING PRODUCT PIPELINE
—o—o—o→	NEW PRODUCT PIPELINE
—/—/—/→	NEW CRUDE OIL PIPELINE
— — — →	BARGE TANKER ROUTE
oooooooo→	TANK TRUCKAGE
Ⓔ	ELECTRICAL POWER PLANT
Ⓟ	PETROCHEMICAL PLANT

◎	EXISTING REFINING CENTER
◎	NEW REFINING CENTER
●	CITY
⊕	NEW DEEP WATER PRODUCT TERMINAL
⊗	NEW DEEP WATER CRUDE OIL TERMINAL
⊞	NEW PRODUCT DISTRIBUTION CENTER
⊠	NEW CRUDE OIL DISTRIBUTION CENTER
HF	HEAVY FUELS
N	UNFINISHED NAPHTHAS
CP	CONSUMER PRODUCTS
ALT.	ALTERNATE METHOD

0 5 10 15 20
SCALE IN NAUTICAL MILES

VAN HOUTEN ASSOCIATES, INC.
CONSULTING ENGINEERS, NEW YORK

PUERTO RICO INDUSTRIAL DEVELOPMENT COMPANY
COMMONWEALTH OF PUERTO RICO
SITE SCREENING STUDY
DEEP WATER PORT & INDUSTRIAL COMPLEX

PETROLEUM CASE D
DISTRIBUTION FROM ISLA MONA

DATE: AUG. 31, 1973 FIG. NO. 49